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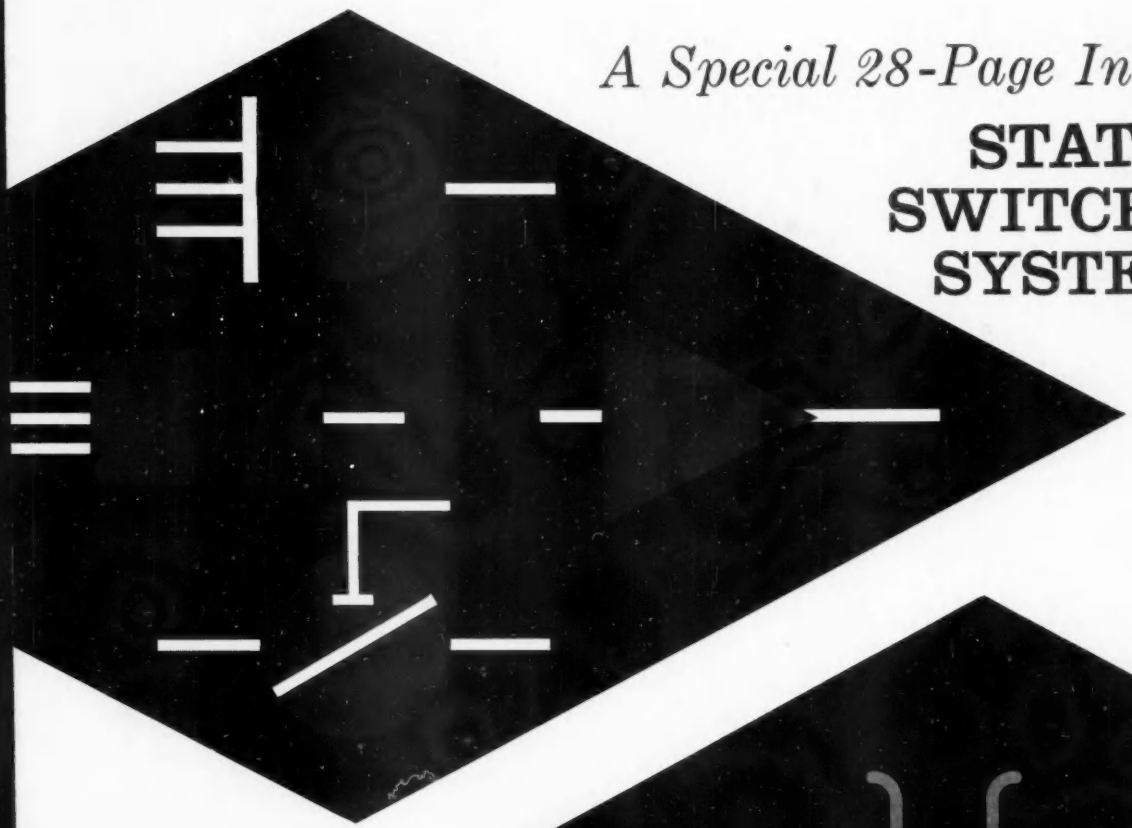
PRICE 50 CENTS

MAY 1957

Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS



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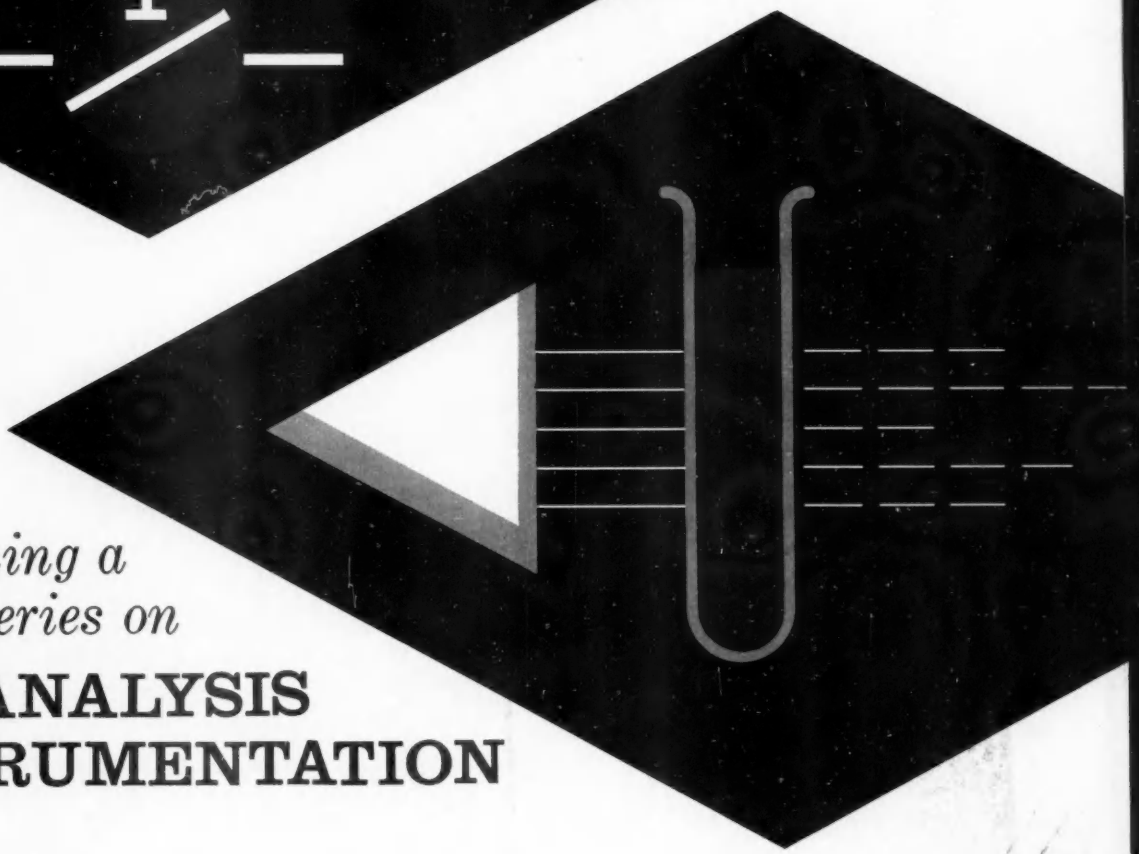
STATIC SWITCHING SYSTEMS



Beginning a New Series on

ANALYSIS INSTRUMENTATION

Librascope XY Plotters

positive mechanical drive

for greater accuracy in graphic data recording

MODEL 200-A for resistance inputs

Control panel configuration of MODEL 200-B for DC signal input

LIBRASCOPE'S UNIQUE "FLOATING GEAR TRAIN," *and conservatively rated conventional vacuum tube and harness circuitry result in static accuracy of 0.1% and dynamic accuracy within 0.5% of full scale, at a tracking rate of 5 inches per second.*

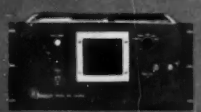
The Librascope Models 200-A and 200-B XY Plotters are engineered for accuracy, rapid response, and ease of operation. The positive mechanical drive of the Floating Gear Train eliminates lost motion, cable stretching or alignment adjustments, normally found in the cable tape or lead screw type of drive. The new, simplified plotting pen of one-piece design—used for point or continuous plotting—eliminates bottles and tubes—permits rapid changing of ink colors. Easy to load and always visible, the plotting table accepts paper up to 11" x 17". Point plotting or curved tracing is accomplished with equal ease with one-second full scale response. A variety of input accessories are listed below.

MODEL 200-A can utilize any external resistance potentiometer as an input transducer associated with each axis. Independent 10 to 1 scale expansion and origin positioning controls are provided. Facilities for external control of the pen drop solenoid and for simultaneous control of external equipment through switch closures, are provided.

MODEL 200-B, used for DC signal input, has full-scale sensitivities of five millivolts and an input impedance of 1,000 megohms in the millivolt scale ranges. Drift-free operation is assured by chopper-stabilizing the voltage inputs against an Epply standard cell reference.

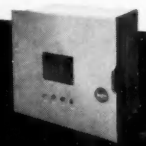
READILY ADAPTABLE FOR RACK MOUNTING

Librascope XY desk model plotters are readily adaptable for mounting in standard RCA and RMA racks, for which accessory hardware is available at slight extra cost.



LIBRASCOPE PUNCHED CARD CONVERTER

Provides for the conversion of data read from IBM punched cards into analog signals that the MODEL 200-A Plotter can accept as inputs.



LIBRASCOPE PUNCHED TAPE CONVERTER

Converts the digital information read from punched paper tape into electrical signals suitable for the control and actuation of a MODEL 200-A Plotter.

LIBRASCOPE X-Y DECIMAL KEYBOARD

Consists of three-decimal bank for each axis with associated plus minus keys. Features Librascope designed positive-action self-wiping contacts.

LIBRASCOPE BINARY CONVERTER

Translates X and Y coordinate information received in the form of binary signals into analog signals for automatic point plotting by a MODEL 200-A Plotter. Has a capacity of nine binary digits and a resolution of one part in 512.

Career opportunities exist at Librascope for qualified engineers, physicists and mathematicians. Learn about Librascope's new "Creative Project Development Teams." Contact Glenn Seltzer, Employment Manager.

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A flick of your finger gives you

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Only the new GEDA Automatic Problem Analyzer *completely* checks computer programming and operation.

Here's one of the greatest advances in computer speed and reliability. It's the new GEDA Automatic Problem Analyzer — standard equipment at no extra cost on *every* GEDA A-14 Goodyear Electronic Differential Analyzer.

Here's how it works:

Switch the computer control to CALIBRATE. Then simply dial the "call" number of the first active channel in your problem. From here on every existing output in the computer, *whether linear or nonlinear*, is scanned and its *position and value* indicated. Repeat the dialing process for each active channel in succession. Then, compare the output readings with your set-up diagram. You know at once whether: (1) all connections are properly made; (2) unwanted connections exist; (3) *every* amplifier, multiplier, function generator, coefficient potentiometer, etc., used in the problem is operating properly; (4) every coefficient in the computer has been properly established, and (5) all initial conditions are present and correct.

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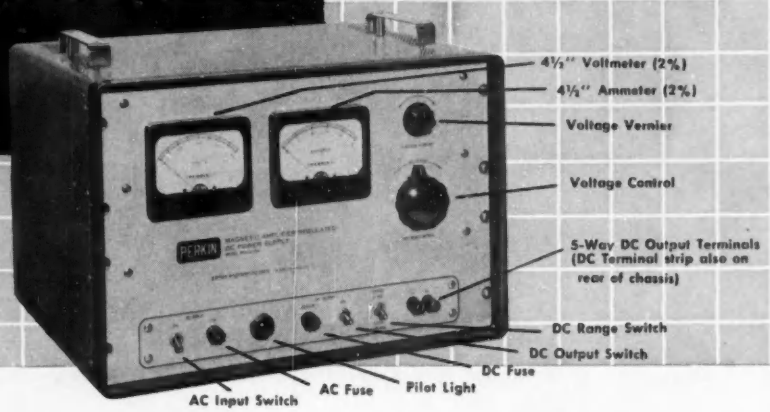

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24-32	10	±½%	28-10WX
24-32	30	±½%	28-30WX
5-40	30	±1%	MR 1040A
24-32	100	±½%	100 XA

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AC INPUT: 105 to 125 volts, 1 phase, 60 cps. (8 amps, Input)

RESPONSE TIME: 0.1 to 0.2 seconds maximum.

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Control ENGINEERING

MAY 1957 VOL. 4 NO. 5

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS
Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

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Orville E. Orbom, chief electronics engineer at Allegheny Ludlum Steel Corp., represents a new caste of engineers in the steel industry. Specializing in industrial automatic control and the design and application of special-purpose computers, he helps keep his company in the fore in the competitive steel market (see page 22). After graduating from Augustana College in 1948 as a physics major, Orville joined ALCOA to develop instrumentation for the analytical chemistry field. But, urged on by J. R. Churchill of ALCOA, his interest gradually shifted to encompass both measurement and control. An opportunity to devote full time to industrial machinery control prompted the switch to his present position. Membership in the ISA, ACS, and IRE helps him keep abreast of the field.

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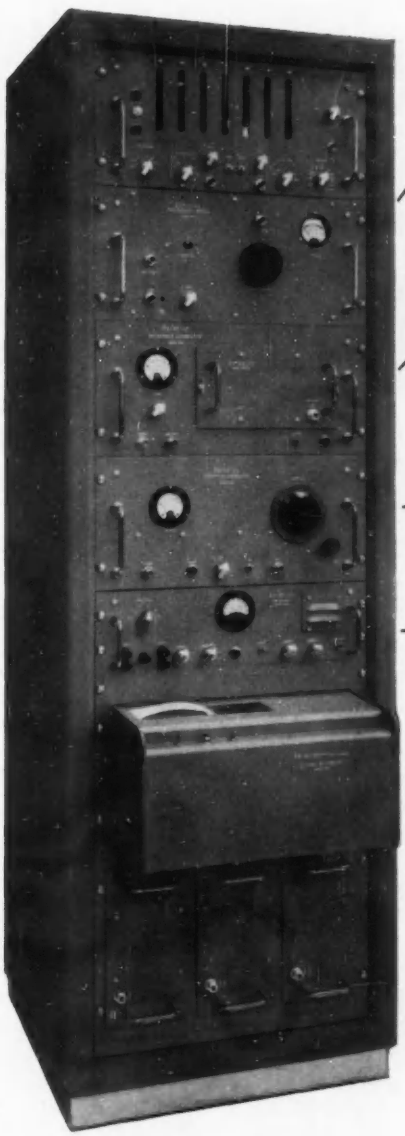
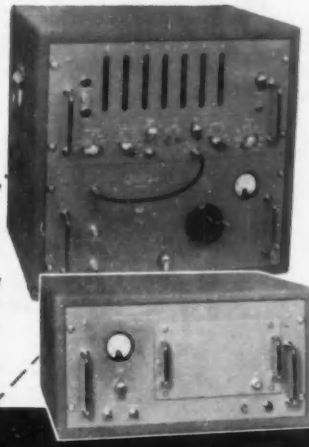
The Frequency Meter That Grows With The Job

Berkeley Model 5571



Typical automatic frequency measurement and logging system showing (top to bottom) Model 5571 Frequency Meter, Model 5580 Reference Generator with Model 5581 Plug-in, Model 5585 Selective Amplifier, Model 5590 WWV Receiver, and Model 1452 Digital Recorder.



Model 5571 0-42 mc Frequency Meter; price, $1,745.00

Model 5580 Reference Generator, with 5581 series plug-ins, extends range to 515 mc. Price, Model 5580, $300.00; 5581/4 plug-in (42-155 mc) $150.00; 5581/15 thru 48 (152 to 515 mc in 33 mc bands), $100.00 each.

Model 5585 Selective Amplifier provides 100 microvolt sensitivity in the 0-42 mc range. Price, $425.00

Model 5590 WWV receiver permits calibration of 5571 within ± 2 parts in 10^8, for use as secondary frequency and time standard. Price, $495.00

Model 1452 Digital Recorder automatically prints readings on standard adding machine tape. Price, (6-digit), $850.00

Note: All prices f.o.b. factory, subject to change without notice.

FLEXIBILITY...

here's the **one** frequency meter that won't be out-dated as your requirements grow or change. By adding matched accessory units, you can extend its range to 515 mc, add a WWV receiver for calibration within ± 2 parts in 10^8, or a digital recorder to print measured frequency automatically on standard adding machine tape.

VERSATILITY...

functions as a frequency ratio meter, 0-1 mc period meter, 1 μsec to 10,000,000 sec time interval meter, or 0-2 mc EPUT* meter as well as a 0-42 mc frequency meter.

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Why not get the facts? Write now for new Berkeley Frequency Measuring Equipment bulletin; please address Dept. L-5.

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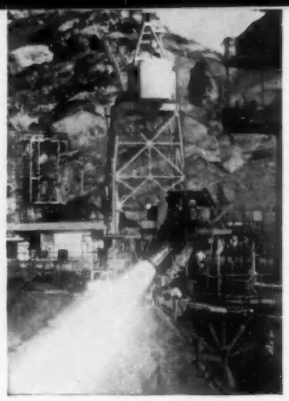

performance test

Brush Recording Systems at Rocketdyne, a Division of North American Aviation, Inc., directly record stress, acceleration, and acoustic values of rocket engines under test.

In all types of applications...

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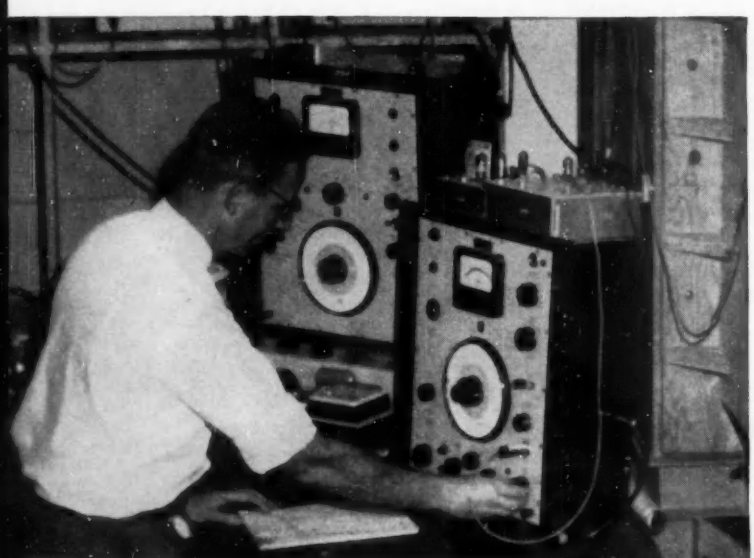
When selecting recording instrumentation for either military or industrial research and development, you want equipment that is proved by experience. Remember—there are more channels of Brush direct-writing oscillographs in use than all other makes combined.

This equipment offers the widest range of recording speeds available, to provide excellent readability for a wide range of signals. You have a choice of ink writing or electric writing, available in console, rack mounted or portable units.

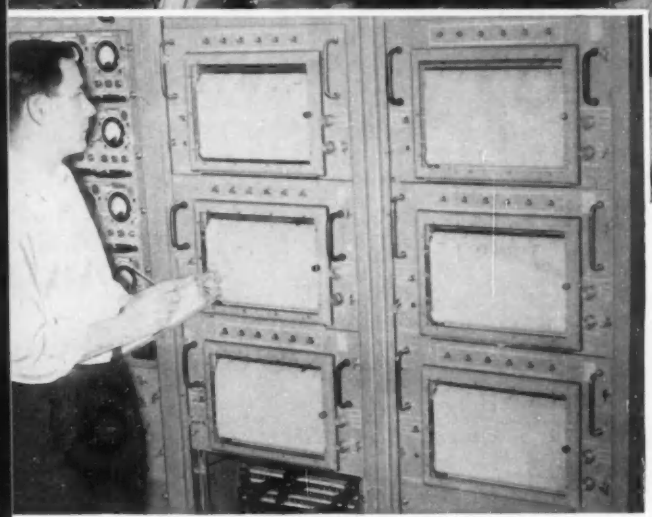
The direct-writing frequency range, from d.c. to 100 cycles per second, covers the great majority of requirements for measurement of physical phenomena. Thus you can instantaneously record stress, strain, vibration, torque, force, and many electrical variables. Select *BRUSH* for equipment backed by unmatched experience.



complete frequency spectrum analysis for noise tests

With a Brush-Bruel & Kjaer Spectrum Recorder, a complete frequency spectrum analysis can be performed in a matter of seconds. This instrumentation operates *automatically*—thus saves hours of engineering time. And it presents recorded data in one-third octave steps—a form in which information is most meaningful and useful to noise reduction programs.

Shown at left is an aircraft test setup measuring loss in acoustic transmission through fuselage wall panels. This is one of scores of complete systems for sound, noise, or vibration analysis using Brush-Bruel & Kjaer equipment.



Official photograph U.S. Navy

telemetering

Over 100 Brush units at the Naval Air Missile Test Station at Pt. Mugu directly record data telemetered from missiles such as the Regulus I. Instruments record an almost limitless variety of functions and conditions, including pitch, yaw, acceleration, pressure, strains, etc.

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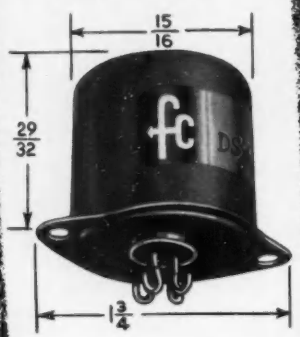
MODEL DS-3



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FOR TWO-SPEED SYNCHRO SWITCHING

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Please send Product Bulletin DS-3 giving complete specifications and application data on Feedback's Synchro Data Switch.

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SHOPTALK

Steel steals a march

On Sept. 20, 1954, Gordon S. Brown told the Seventh International Convention of the United Steel Workers, "Steel has become an industry wherein I would not think it facetious if the workmen wore tuxedos on the job" (CtE, Nov. 1954, p. 17). If dress really is the criterion of the status of steel, then the past 2½ years should have seen a transition from tuxedos to white tie and tails. Programmed mill setup, precise gage control, optimized furnace operation, studies of process dynamics, and rumors of completely integrated systems indicate that control is taking steel by storm. To see for themselves, CtE editors visited several control makers and industry user engineers. We were impressed by what we saw and heard, and think you will be also when you read about it on page 22.

Staffing up

In 1948 numerical control of machine tools was like a gleam in a father's eye. But even then Harry Winston Mergler saw a need for these techniques in producing prototype gas-turbine blades at the NACA Lewis Flight Propulsion Lab., and so organized the Automatic Machine Tool Control Section, of which he was head till he joined the Mechanical Engineering Dept. staff at Case Institute a short while ago. As of this month, Harry joins the CtE Board of Consulting Editors to keep us on the beam in the important area of the recorded-information control of industrial processes. Unique in his field, Harry received his PhD in digital methods and numerical control from Case last year; he holds several control patents, teaches one of the first formal courses in machine tool control, and consults for several major manufacturers of machine tools and process equipment. Harry's arrival balances the Board of Consulting Editors like we try to balance the editorial content of an issue. He and his cohorts (Gordon, Gene, and Jack) make sure we don't miss any bets in our major fields of interest.

Art looks out for you

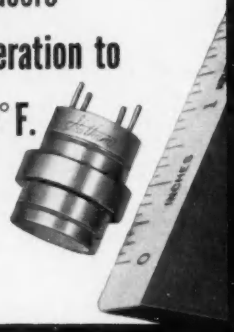
A belated welcome to Art DeWeerdt, who fills the newly created post of Circulation Manager. Art says that he will "personally look after the interests of CtE subscribers". To do this he'll try to improve delivery of CtE, speed up the entry of new and renewal orders, and seek out new readers who should subscribe.

THE MIDWESTERN 591 RECORDING OSCILLOGRAPH

For test recording where dependability and accuracy count most . . . the 591 is being utilized successfully in laboratories, at missile down-range stations and in high performance aircraft. It includes these outstanding features —electronic timing which permits multiplexing of two or more units and the use of external pulse source to produce timing lines—immediately interchangeable plug-in ac or dc power supply units—dual filament galvanometer lamps, and many others. For additional information on this field-proven instrument, call, wire or write our Tulsa offices.

MIDWESTERN INSTRUMENTS
41ST AND SHERIDAN / TULSA, OKLAHOMA

Miniature Pressure Transducers for operation to + 400° F.



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FEEDBACK

PROBLEM FORUM

Here are two opportunities for readers working on program-controlled machines to practice their know-how. Submit your solutions to both problems—one, the tape-control of a sewing machine, and the other, a card-reader and an electric head for a drill press. What machines would you recommend? How would you program them? Be specific. We will pay for the best solutions offered.

Don't forget to submit unique measurement and control problems which *you* have. Try our readers on them. One of our over-30,000 may have the answer to *your* problem, just as you may have the answer to Mr. Mason's problems.

To the Editor—

There are two sides to our business—machine tools and high-grade clothing. Your magazine keeps us in touch with the latest developments in the automatic control of machine tools. But why is the sewing machine not automated?

First Problem

We are very anxious to develop a tape-controlled sewing machine. Two-dimensional control would do for a machine with a rotary table and a head which sews both forward and back. Could we program the sewing of well-pockets (i.e., the outside breast pockets of jackets and waistcoat pockets) and jetted pockets? You recently published an article which indicates that what we want is getting nearer: "Nylon Stockings Tape-Programmed to the Wearer", Charles Fegley, page 114, June 1956 issue. What specific suggestions and plans can your other readers give us?

Second Problem

On page 103 of the December 1956 issue you published an article entitled "Digital Machine-Tool Control Simplified", T. J. Thomas. Where can I purchase a laboratory-type card-reader as shown in the article? Would the same system work for an electric drill-head instead of a pneumatic one?

A. C. Mason
Sutton-Coldfield
Warwickshire, England

Putting the record straight

To the Editor—

The table on page 116 of your April issue (analog-to-digital converters) on shaft-position encoders misrepresents the encoders produced by the DATEX Div. of Giannini. The article indicates DATEX has only one model encoder, whereas we actually can supply many models. In addition, the facts pertaining to the model that is listed are misstated as follows:

1. The sampling rate is given as a maximum of two per second. Actually the sampling rate of our encoders is limited only by the readout device. Reading rates of up to 10,000 per second are possible using appropriate circuits.

2. The second misstatement is that the encoder "shaft must be stopped for readout". Our devices were among the first on the market that could be read "on the fly".

We feel that sufficient damage has been sustained by us from the original article that we would like to supply you with factual information concerning our devices. This might be accomplished in the form of another letter from me to your magazine.

John W. Bodnar
Sales Manager
DATEX Div.
G. M. Giannini & Co., Inc.

Sorry for our slip. We'll be glad to publish the correct information in our Feedback section as soon as you furnish it to us. Ed.

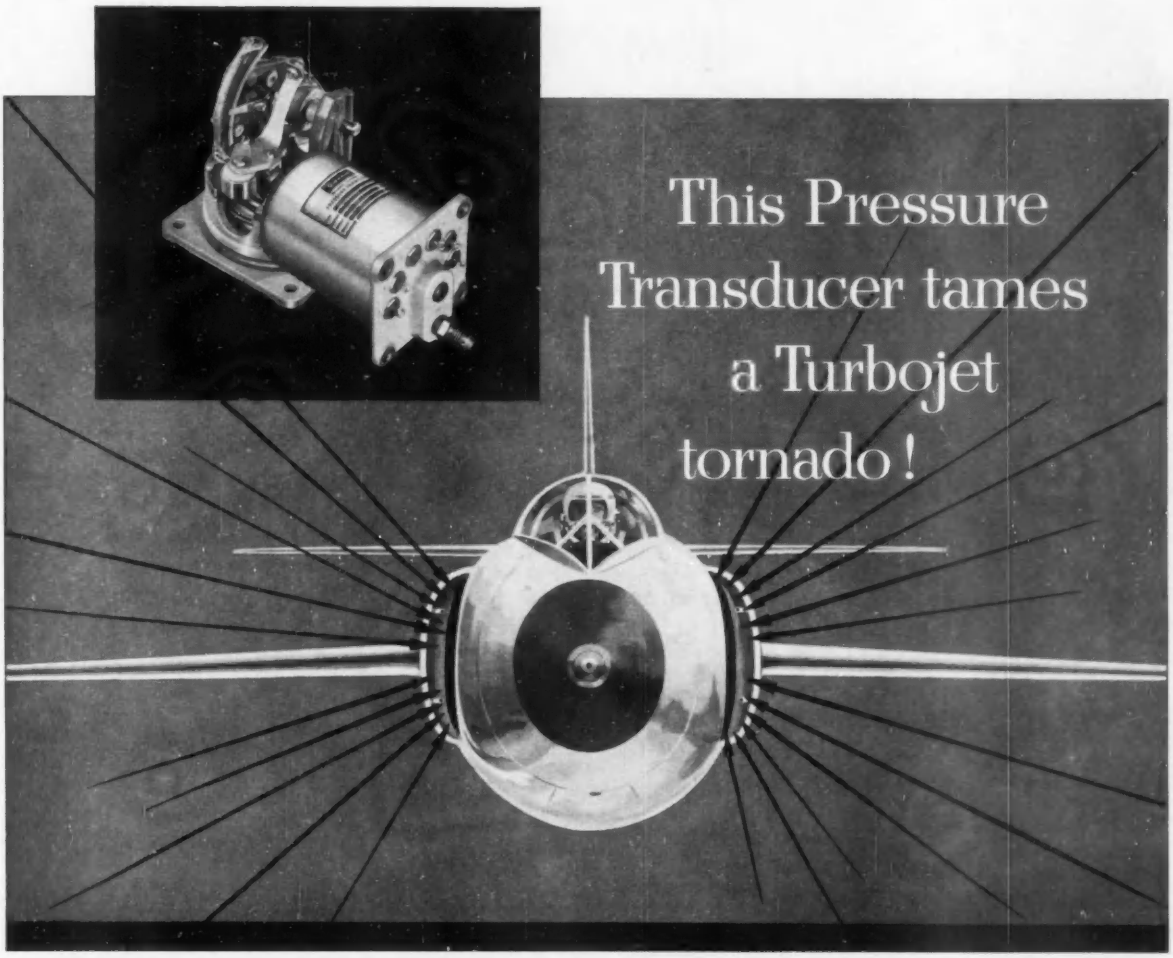
Student hunts job and vice versa

To the Editor—

Can you advise me as to how I may obtain names and descriptions of outstanding companies in the control engineering field so that I may be in a better position to evaluate the companies for a job.

Marvin Robinson
Tarrytown, N. Y.

Look through issues of CONTROL ENGINEERING. In the Classified



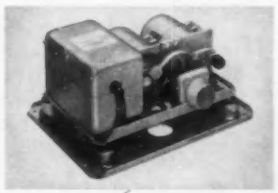
This Pressure Transducer tames a Turbojet tornado!

Controlling the tornado of intake air consumed by supersonic jets is the latest assignment of Giannini's High Resolution Pressure Transducer. This versatile instrument plays a key role in maintaining optimum efficiency of today's newest and most advanced high performance turbojet engines.

Two of these transducers form the heart of the Giannini designed and produced Variable Inlet Control System which limits diffuser air to a steady subsonic flow at all speeds and altitudes. Static and total air pressures in the diffuser throat are sensed by absolute and differential versions of the transducer, and this data is transmitted to a computing element. The ratio of pressures is compared to a stable reference, and error signals are fed back to position a variable obstruction, or ramp, in the inlet duct.

By using these unique pressure instruments as sensing elements in the Giannini system, several distinct advantages result: the transducers can be located near the pressure probes, minimizing pneumatic tubing length; no stable amplifier is required since the high level output of the transducer potentiometer pickoffs can be used directly; no repeater servo is required; the system is flexible, control pressure ratio being altered merely by adjusting the reference; the computer can be located remote from the transducers.

The Giannini Variable Inlet Control System is typical of applications to which this instrument can be put. **Capabilities** of 350 volt output, 2000 wire resolution, 0.8% linearity, repeatability to 1% of *reading*, and its rugged insensibility to vibration and shock make it ideal for use in the most critical airborne controls and systems... In case you're not interested in taming a tornado—perhaps it's only a mild breeze—Giannini High Resolution Pressure Transducers are admirably suited for telemetering and control applications requiring the ultimate in accuracy and sensitivity.



Giannini Variable Inlet Control System

Write for Bulletin 451212.

Giannini PRECISION INSTRUMENTS & CONTROLS

G. M. GIANNINI & CO., INC. • 918 EAST GREEN STREET • PASADENA, CALIFORNIA

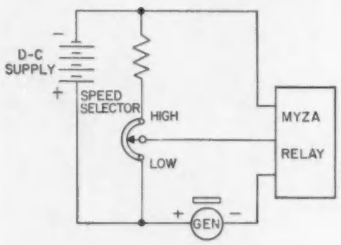
THE MARK OF QUALITY
BARBER COLMAN

ultra-sensitive relays

HELPFUL DATA FOR YOUR CIRCUITRY IDEA FILE . . .

(No. 5 in a series by Barber-Colman Company)

The circuit drawing below indicates just one of the hundreds of ways many manufacturers are utilizing Barber-Colman Micropositioner ultra-sensitive relays to solve complex control problems. Could this be the answer to some of yours, too?



SPEED CONTROL WITH TRANSISTORIZED MICROPOSITIONER ®

The MYZA transistorized polar relay used in the circuit above is an adaptation of a standard Barber-Colman Micropositioner, but with a built-in preamplifier so that it requires greatly reduced input power to operate the contacts.

Thus, close speed regulation is possible using this relay to detect the difference between the "control" voltage supplied from an adjustable resistor and the output of a small d-c generator (Barber-Colman permanent-magnet type) coupled to the rotating member, such as a lathe spindle.

If the generator (variable) voltage is equal to the fixed (control) voltage, both coils of the relay are energized equally, and neither contact will be closed. A change in input from either direction will cause the relay to close a contact, actuating an alarm system, or causing the mechanism to increase or decrease speed, depending on the polarity of the signal.

MYZA relays are designed to order to meet each application's circuit requirements. Write for technical bulletin F-7754-2.

BARBER-COLMAN MICROPOSITIONER ® POLARIZED DC RELAYS

Various types . . . plug-in, solder-lug, screw terminal, hermetically sealed. Operate on input powers of 40 to 1,000 microwatts for use in photoelectric circuits, resistance bridge circuits, and electronic plate circuits. Send for data.

BARBER-COLMAN COMPANY
Dept. Q, 1848 Rock Street, Rockford, Illinois

FEEDBACK

Advertising section you will find many job openings advertised by outstanding companies in the field served by this magazine. At the same time, you will find it worthwhile to look at our Industry's Pulse in the September 1956 issue. It contains a representative listing of companies in our field, and these are companies that do control-systems-engineering work.

Send in a complete description of your experience and qualifications. Prominent companies in our field continually ask us for help in locating competent new employees. We will be glad to go over your resume and discuss it with department heads of appropriate companies. Ed.

The Greeks had symbols; do we?

TO THE EDITOR—

The Publications Departments of our various Collins plants have been engaging in a Publications Standards Program in which we set forth standards of writing and standards of technical illustrating, as well as many other phases of standards on instruction books, technical reports, etc.

I am on the "Servomechanism Symbols" Committee and am seeking a basis from which such symbols have arrived. I doubt that the term "Servomechanism Symbols" is appropriate, but we do not have a better one. We have not found much in IRE Standards or JAN-STD-15, and since we noticed that your magazine CONTROL ENGINEERING has made wide use of such symbols we thought that you might be in a position to help us.

Can you quote the authority for such symbols? Do you have any guide books that contain such information? Any help you can give us along these lines will certainly be appreciated.

Henry Heusinkveld
Collins Radio Co.
Cedar Rapids, Ia.

Mr. Heusinkveld's yelp for help arrived via our art director, Jack Gordon, who asked us to apply first aid. The problem is that Mr. Heusinkveld is using, according to the sample submitted with this letter, a mixture of a block diagram and a functional schematic. Why shouldn't he, if the mixture conveys what his designer has in mind? We do not suggest that his designer unscramble the mixture. Instead, we urge him to:

1. Check whether his symbology follows that given in the American Standard Association's "Graphical Symbols for Electrical Diagrams", ASA Y32.2-1954. This standard was co-sponsored by AIEE and ASME and approved in 1954.

2. Find out what was said at the Industrial Educational Institute's Special General Electric Seminar on Simplified Drafting Practices, held last month at the Hotel Sheraton-Astor, New York. Address of the institute is: 25 Huntington Ave., Boston 16, Mass.

Between the two he should get answers to his simpler questions and should be better able to formulate the tougher ones. Ed.

Plans controlled pass-along

TO THE EDITOR—

We are attempting to expedite the handling of periodicals which are received by our Research Library. We wish to circulate the tables of contents of selected periodicals rather than the magazines themselves.

Please advise me if you are able to send us one copy of the tear-sheets of the table of contents for your publication at the time of publication of each issue. This would allow us to make new information available to the engineers and chemists in the laboratory much earlier than at present.

F. E. McKenna
Air Reduction Co.
Murray Hill, N. J.

Glad to be of service, particularly when it means CONTROL ENGINEERING will reach a greater number of qualified readers. Our Reader Service Dept. will send you, monthly, our two-page contents leaf. Its brief description of the contents of each article and department should help your engineering personnel select the articles specifically interesting to them. Compile their selections and write Mrs. Florence Baxley, manager of our Reader Service, for quotes on the reprints of articles which you need. Ed.

Still more on Shepard article

TO THE EDITOR—

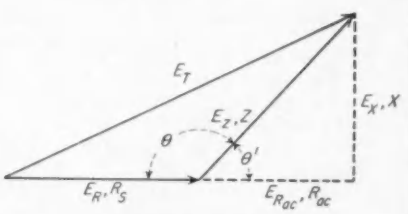
Reading my February copy of CONTROL ENGINEERING, I stumbled across H. Havlicek Jr.'s letter [page 16—Ed.] which commented on the article of E. S. Shepard Sr. in the August '56 issue. ["Simple Wide-Band Impedance Measurements", pages 104 and 105, tells how to use the **three-voltmeter method** graphically to determine the effects of loading, resonance, reflection, etc., on the frequency response of transducers and other system elements whose circuits have significant electrical impedance. Ed.] Of

course, the first thing I did was to pull the August '56 copy and read the article. Both the article and the letter show the method as used in the laboratory. There its accuracy is not only limited by the inherently inaccurate meter but also by the mathematical approximations in Havlicek's approach and by drafting accuracy in Shepard's.

My problem is different. With nine engineers I have to do the work of 18, instructing semi-skilled production test personnel to make complex measurements to a previously unheard of accuracy. We can leave no interpretation to the testers. In determining the complex parameters of, for instance, iron-core devices, it is, more often than not, impossible to correlate test results obtained under arbitrary laboratory conditions with actual behavior in the circuit for which they were designed. This rules out a large number of commercial equipment such as bridges and impedance testers because many of them operate at fixed voltages and frequencies. They are variable within only narrow ranges and often the variation complicates interpretation of their indications. Certainly no instruments available have sufficient adaptability to simulate actual "circuit conditions".

However, if used right, the three-voltmeter method is not only inherently accurate, but measurements of the impedances can be arranged so that they are not tedious, time-consuming, or complicated. Here is my derivation and technique.

Refer to Mr. Shepard's Figure 1. The voltage-vector diagram for the basic test circuit shown is:



Note that the impedance diagram is analogous to the voltage vector diagram. Divide all voltage vectors by E_R/R_s to obtain impedance vectors. According to the law of cosines, the relationship which describes the voltage vector diagram is

$$E^2_T = E^2_R + E^2_Z - 2E_R E_Z \cos \theta \qquad (1)$$

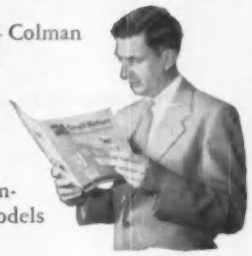
This derivation is slightly simpler than Havlicek's. Given the three voltages, E_T, E_R, and E_Z, the value of R_s, and the test frequency, one can manipulate the equation to find Z, X, L, and R_{ac} from them. Because the necessary mathematical manipulations are unwieldy for production test person-

THE MARK OF QUALITY

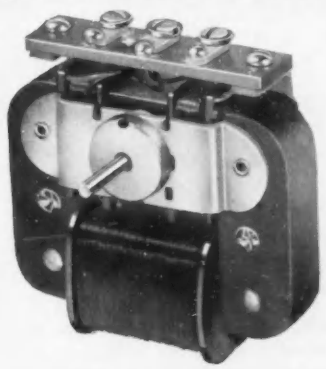
BARBER COLMAN

Small Motors

condensed catalog helps select exact motor needed

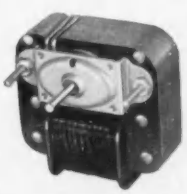


Get this helpful catalog of Barber-Colman a-c shaded pole motors. Designed for applications requiring long life, rugged construction, these quality motors with high starting torque, low-inertia rotors provide quick, positive starting under adverse conditions. Various models of the four types shown below.



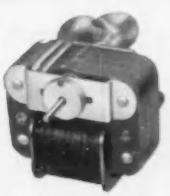
REVERSIBLE MOTORS

Adaptable to a variety of control circuits to meet many different requirements demanding a compact and powerful fast-reversing motor. Widely used for servo-mechanisms, remote switching and positioning devices, voltage regulators, pen drives. Available with gear trains, open or enclosed, in wide range of ratios. Low-inertia rotors permitting rapid reversing and follow-up make these motors ideal for many electronic control circuits.



UNIDIRECTIONAL

For driving pumps, projectors, blowers and fans for refrigerators, gear trains for vending and office machines, etc.



SYNCHRONOUS

For chart drives, timers, microfilm cameras, oscillographs, and similar applications.

GEARED

For vending and office machines, rotisseries, TV tuners, program switches, etc. Model shown for overhanging loads.

the complete line of Barber-Colman motors includes unidirectional, synchronous, and reversible motors — up to 1/20 hp. With and without reduction gearing — open or enclosed types. Expert engineering service available to help you get the exact motor for your application. Write today for your free copy of Catalog F-4271-7.

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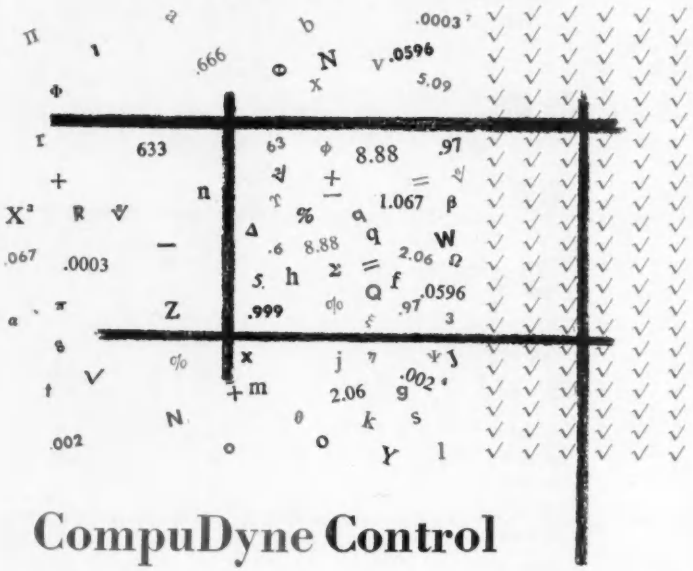
ON AERONAUTICAL RESEARCH AND TEST FACILITIES



CompuDyne Control

... increases data *output* and *validity*

CompuDyne Control Systems establish the constants necessary for *valid* aeronautical test work . . . regulate the most severe process transients. Employing computor-dynamic techniques, they attain steady-state conditions . . . step, ramp or otherwise program variables . . . at higher speeds, with greater accuracy than ever before possible.

Time saved in attaining test conditions is a vital factor in data output. Accuracy is essential for data validity.

Prior to manufacture, CompuDyne Control Systems are pre-tested by means of analog computor studies. You know exactly what performance to expect. CompuDyne Control Systems are designed, built and installed within your facility . . . from conception to operation . . . on a guaranteed performance basis.

INFORMATIVE NEW BULLETIN entitled, "VALID DATA . . . economically produced by dynamic process control" will be sent to you upon request. Write or telephone.

For Test Facilities . . . Typical CompuDyne Control Systems

Aircraft Engines & Components
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FEEDBACK

nel, make $E_R = E_Z = 1$. Equation 1 then simplifies to

$$E_T/E_Z = 2(1-\cos\theta)^{1/2} = 2(1+\cos\theta')^{1/2}$$

$Z = R$, if R, is adjusted so that the voltage drop across it is the same as that across Z. Since the ratio

$$E_T/E_Z = 2(1+\cos\theta')^{1/2} = 2\left(\frac{1+\cos\theta'}{2}\right)^{1/2},$$

or $2\cos\theta'/2$,

its numerical value is between 2 and 2½ for θ' between 0 and 90 deg. Therefore the test boils down to measuring the voltages across resistance and impedance, and adusting the resistance for equal voltage drop across it and the impedance, then measuring the total voltage and looking up in a trigonometrical table ratio $E_T/2E_Z$.

These are the rudiments of my answer to both the article and the letter. However, I have gone further by designing a graph which directly reads θ', cos θ', and sin θ' for every ratio. And I have developed a simple instrument, and techniques for using it, which exclude the meter inaccuracy and which give answers correct to within 1 percent. They are accepted by vendors supplying my employer, Hughes Aircraft Co., with iron core devices.

Gene J. Hegedus
Hughes Aircraft Co.,
El Segundo, Calif.

Feedbacker Hegedus has offered a description of his method, including his graph and details of his instrument. We will publish it soon. Ed.

Educator seeks source of equipment

To the Editor—

I am in charge of a servomechanism course at the Engineering School of the Brazilian Army and have been trying to set up a servo lab in the EE Dept. of this school.

We are, nowadays, in great need of a pen recorder and a low-frequency sine-wave generator to run routine servo experiments. I would appreciate it if either you get in touch with manufacturers of these equipment to have them send me data and prices, or just mail me their addresses so I can write directly to them.

Haroldo C. de Mattos
Escola Technica do Exercito
Urca, Rio de Janeiro, Brazil

We have circulated your letter to a number of manufacturers. While waiting for their quotations, take a look at the advertising in our magazine. You'll find several manufacturers who offer just what you need. Ed.

at last a completely new kind of regulator!

ACTUALLY THREE REGULATORS IN ONE—*PLUS* MULTIPLE SENSING!

The APR 1010 combines many *new* regulation and sensing systems in *one* versatile package. Here's flexibility of operation never before possible . . . saves space, eliminates instrument duplication, means greater economy in engineering operations.

- **RMS VOLTAGE REGULATION**
- **AVERAGE REGULATION**
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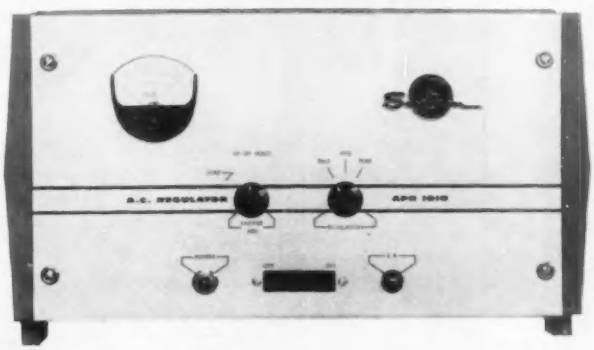
- ***FIVE* PRINCIPAL SENSING ARRANGEMENTS**

1. INTERNAL 2. EXTERNAL 3. REMOTE 4. CONSTANT CURRENT 5. DC

ELECTRICAL CHARACTERISTICS:

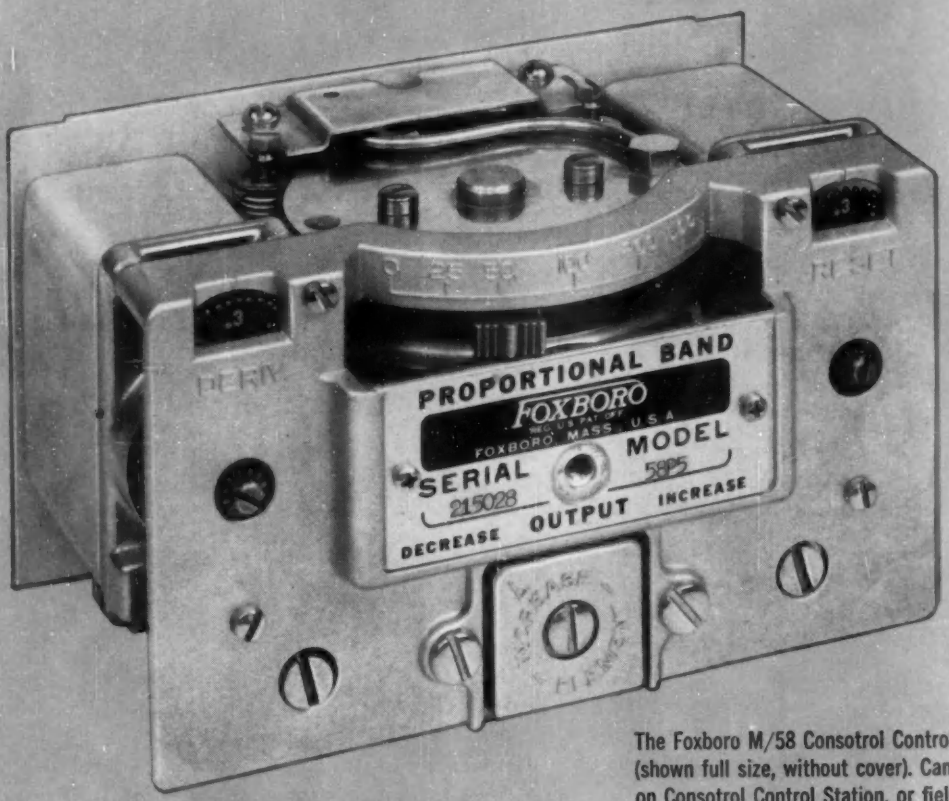
Input	95-130 VAC, 1ϕ (50 or 60 cps ±10%)
Output	115 VAC, adj. 110-120V
Regulation accuracy (RMS, average, or peak, switch selected)	±0.1% against line ±0.1% against load
Distortion	3% max.
Load	0-1000VA
P.F. range	Unity to 0.7 lagging
Recovery time	0.1 sec.

Write for complete technical data.



SORENSEN & COMPANY, INC. Sorensen® **STAMFORD • CONN.**

In Europe, contact Sorensen-Ardag, Eichstrasse 29, Zurich, Switzerland, for all products including 50 cycle, 220 volt equipment.



The Foxboro M/58 Consotrol Controller (shown full size, without cover). Can be panel-mounted on Consotrol Control Station, or field-mounted.

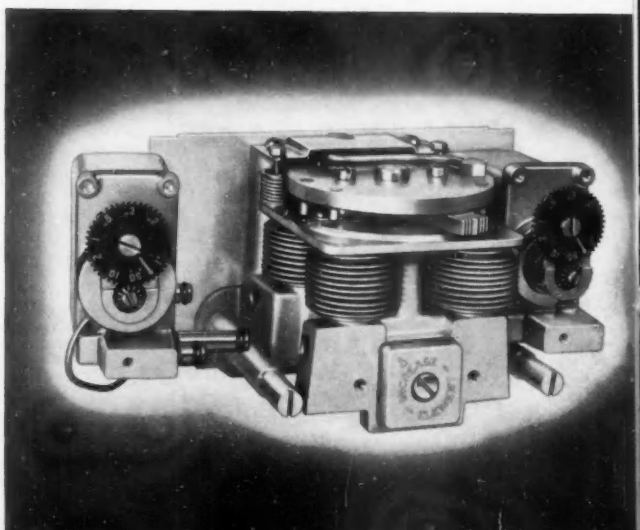
THE FOXBORO M/58 CONSOTROL

The M/58 Controller's Revolutionary Floating Disc System

Here's the exclusive Foxboro design development that gives M/58 Control its unique versatility, precision, and stability. The floating disc and matched bellows assure uniformly high controller sensitivity and pin-point control action, even at widest settings of the proportional band. Lever-set proportional band adjustment is calibrated to 500%.

Component Construction Gives Unrivaled Versatility

Not only is the complete controller easily detachable as a unit, but also, each component is a "plug-in" unit. For example, reset plugs in at right as shown; derivative, similarly, at left. All 4 control actions, with 2 reset ranges, are available and easily adjustable to widest variations in operating conditions. Proportional action from 1 to 500% quickly set by lever.



Outperforms all other controllers!

...the controller with the FLOATING DISC

If you think this claim is exaggerated, just put a Foxboro M/58 Consotrol* Controller on your process. The tougher the job, the more it will outperform other controllers! Or ask any present user . . . many of the largest, most progressive petroleum and chemical processors are using hundreds of these instruments. They will unhesitatingly confirm that this exclusive Foxoboro development has put their processes "on stream", automatically and smoothly from the control room, without false starts or confusion.

The M/58 Controller can do the same for your process. The flexibility of its control functions makes it readily adaptable to *all* processing techniques. All four actions are available, with two ranges of reset . . . all are easily adjustable to the most widely varying operating conditions. For example, reset and derivative functions plug in . . . proportional action from 1 to 500% can be quickly set by a lever. And calibration is a simple zero adjustment!

Get full details on this simple, truly "universal" Controller. Write for Bulletin 13-19 and ask your Foxboro Sales Engineer for a demonstration. **The Foxboro Company,** 365 Neponset Ave., Foxboro, **Mass., U.S.A.**

*Reg. U.S. Pat. Off.

FOXBORO **CONSOTROL INSTRUMENTS**

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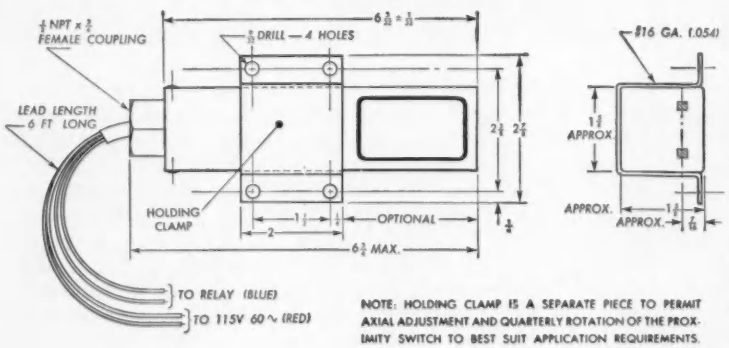
MICRO SWITCH . . . FIRST IN PRECISION SWITCHING

NO MORE DOWN TIME!

No Moving Parts . . . No Tubes . . . Unlimited Life . . .
High Speed, Operation—10 Times per Second

The Honeywell Proximity Switch is a magnetic switching device that employs no moving parts . . . It detects ferrous objects without physical contact . . . The sensing head sets up an electric signal which flows through the magnetic circuitry and operates a remotely-located control relay . . . It will operate as many as 600 times a minute, is unaffected by ferrous chips, and because it employs no moving parts, its life is unlimited; thus, work stoppage and consequent costly down time is eliminated . . . Industry will find many uses for this new switch . . . Conveyors will be kept in operation; counting and similar applications will be done more reliably; machine tools will operate more dependably.

Request Data Sheet No. 119.



NOTE: HOLDING CLAMP IS A SEPARATE PIECE TO PERMIT AXIAL ADJUSTMENT AND QUARTERLY ROTATION OF THE PROXIMITY SWITCH TO BEST SUIT APPLICATION REQUIREMENTS.

Consider these Important Features

No Mechanical Linkages:
Requires no physical contact with workpiece.

No Moving Parts:
Has no electrical contacts or moving parts.

Wearout Proof:
Uses no vacuum tubes or other components of limited life.

Conventional Installation:
Requires no shielded leads, and can be energized from 115 volts 60 cycle power.

Resistant to Environment:
(a) not activated by ferrous chips; (b) potted to permit operation in high humidity, corrosive atmosphere, or presence of cutting oils; (c) protected by heavy steel housing.

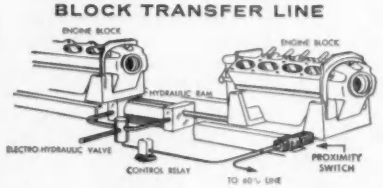
Fast Response:
Will operate up to 10 times per second.

Sensitive:
Can be actuated by a ferromagnetic surface that is only ¼ in. square and 1 in. long. Smaller pieces with special application precautions will also operate this device.

Applications:
Materials Handling Control—For programming the operation of transfer machines in automation equipment.

Limit Switch on Automatic Machine Tools—
For maximum reliability where the wear on mechanical limit switches would necessitate costly shutdown. Can operate in presence of cutting oils, liquid sprays or corrosive atmosphere where conventional electrical contacts would fail.

ACTIVATING ENGINE BLOCK TRANSFER LINE



SPECIFICATIONS:

Excitation—100-125 v, 60 cps, 2 watts (nominal).

Output—(a) switch "on"—12 vdc minimum; (b) switch "off"—4 vdc maximum into 250 ohm load.

Sensitivity—When a block of ferromagnetic material is moved parallel to and within 1/16 in. of its pole face, the Proximity Switch will operate the control relay.

Repeatability—When a block of ferromagnetic material is moved to within 1/16 in. of its pole face, the Proximity Switch will repeat its pick-up and drop-out point within 3/32 in.

Differential—When a block of ferromagnetic material is moved parallel to and within ¼ in. of its pole face, the Proximity Switch will have a differential distance between pick-up and drop-out of less than 7/32 in.

Any MICRO SWITCH field engineer will be glad to work with you regarding the wide applications for this new Proximity Switch.

MICRO SWITCH
A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY
In Canada, Leaside, Toronto 17, Ontario • FREEPORT, ILLINOIS

SID DAVIS **translates the complex**

To many engineers, the damping of a servomotor recalls a torque-speed curve. But to Sid Davis, servo-damping is trying to run a servomotor in molasses. Davis tries to visualize what happens in a system in physical terms rather than theoretical. His most conspicuous talent: making a complex problem easily understandable, by putting highly theoretical concepts into down-to-earth language.

Since his graduation from The Cooper Union with a BEE 12 years ago, Davis has been finding his knack for crystalizing a problem a more potent design tool than theory. His maxim, "Use theory to check, not to design", cuts weeks off development schedules, helps produce answers in hardware in record time.

In his career as an engineer, Sid has shied away from formal theory. He's never taken a course in servo components or systems, although he has taught both at Brooklyn Poly's graduate school since 1947. His professional career started like thousands of others—as a test engineer. He left the test floor of Bendix Aviation to try his hand at design as a junior engineer at Liquidometer, studying nonlinear techniques for measuring liquid levels. In 1947, Davis joined Arma Corp. as a design engineer. For five years he used his unique talents to design and develop servo components; for two years he worked on systems. Then, as chief development engineer at Servomechanisms, Inc., Sid concentrated on application engineering and the design of rotating components.

A propensity for adding hours to his working day propelled Sid into the consulting field. One day in 1951, he noticed a tiny newspaper ad, almost lost on the financial page of *The New York Times*. The ad sought an engineer for part-time consulting on motor design. After receiving an okay from his Arma supervisors, Davis applied and got the job, which called for designing a new servomotor. His simplified design—produced in short order on Saturdays only—helped win a production contract. And Davis had the consulting bug for good.

Still another facet of Sid's career also started in 1951. That was the year he started writing technical articles. His innate ability to take a theoretical condition and express it in simple terms with a minimum of mathematical complication soon made Davis one of the most sought-after technical writers in the servo field, but the technical articles just whetted Sid's appetite to write. His next accomplishment was coauthorship (with CONTROL ENGINEERING's By Ledgerwood) of a 125-page section on motors, clutches, tachometers and mechanical hardware for the *Servomechanisms and Feedback Control Systems Handbook*, soon to be published by McGraw-Hill.

And now he's completing a McGraw-Hill text on rotary components (also with By Ledgerwood).

In his consulting and writing, Sid specializes first in rotating components, then in the design and construction of small feedback systems—primarily for test purposes. Davis' technique in making the complex understandable is rooted in a stubborn belief that a control engineer has got to know how his system works. He puts it this way: "You've got to have a feeling for the things that are happening and how they interact." That's why he carries thousands of vivid impressions around in his head—impressions like the servomotor in molasses.

Sid likes to think that he leaves his technical interests outside his Long Island home when he crosses the threshold. But wife Barbara will tell you that practically every social call or visit by friends turns into an engineering seminar with Sid vociferously arguing for physical approaches rather than mathematical equations. The only time Sid stops thinking in a technical vein is when something mechanical breaks down in the house. By his own admission, he is New York's worst home handyman, preferring to put domestic energies into gardening and playing with his two sons (Ken, 4, and Peter, 2,) rather than into home repairs or do-it-yourself projects.

Here is CONTROL!

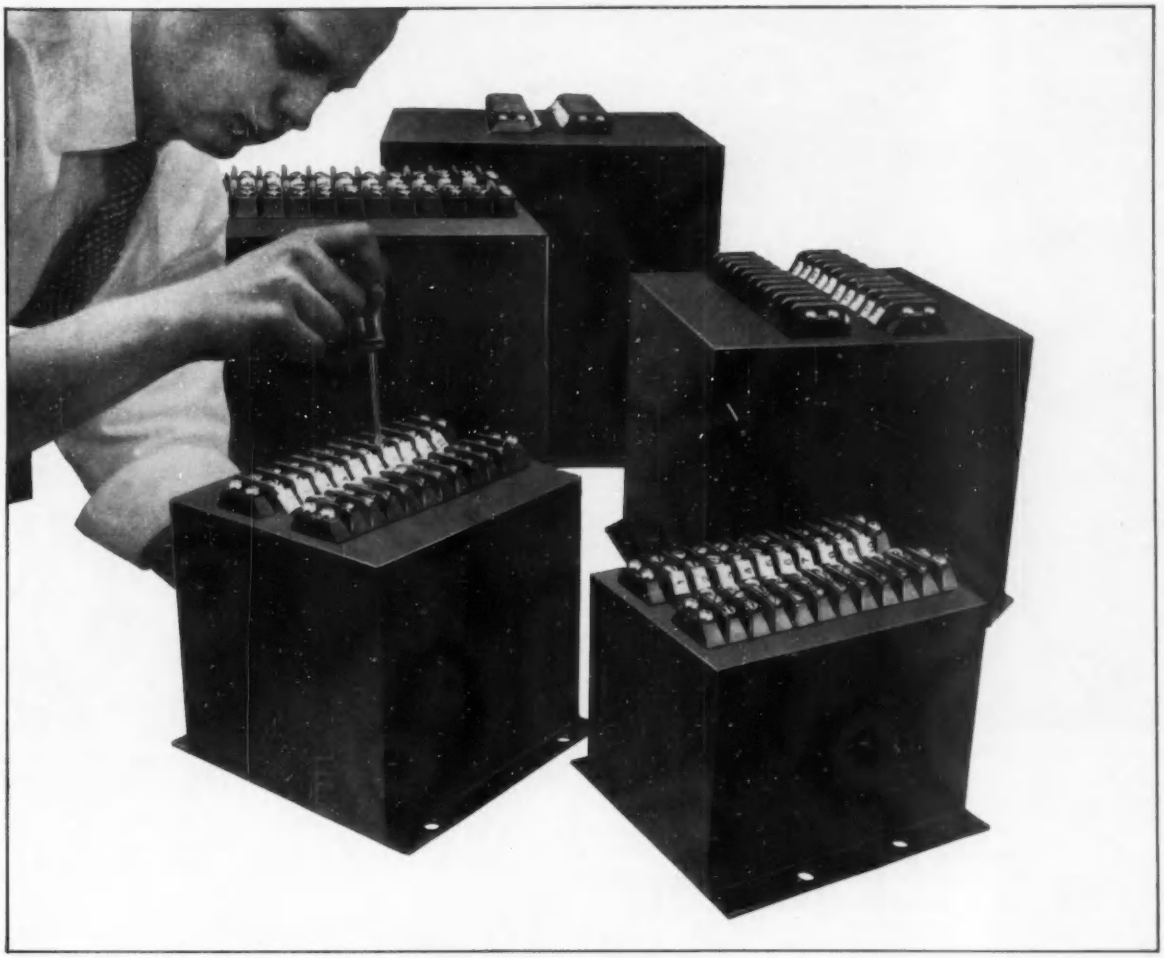
May 1. Important news to engineers concerned with industrial control is announcement of standardized high permeability magnetic control devices now available from "Control," a division of Magnetics, Inc., Butler, Pennsylvania.

"Control's" first products are standard lines of saturable reactors. Twenty-two catalogued reactor assemblies will be stocked and are ready for rapid delivery.

Establishment of "Control" is a major step forward in permitting engineers to take full advantage of long life and ruggedness features of high permeability magnetic devices. It takes these units from the custom-order to the mass production stage with important benefits in engineering convenience and dependability.

In recent years, high permeability magnetic devices have made real inroads in the industrial control field. CONTROL reactor assemblies may be used for such diversified applications as motor control, voltage regulation, automatic battery charging, arc welding control and power amplification of the minute outputs from many types of transducers.

Engineering sales representatives are located in many key areas in the United States. Advertising appears in leading trade publications in May, based on the theme "Reliability Begins With CONTROL."



Now--CONTROL offers you standardized saturable reactors

If you're a design engineer who would be delighted with industrial components which are sensitive and, under normal operation, last virtually forever with no maintenance or servicing, then you'll welcome CONTROL's *standard* lines of saturable reactors.

With CONTROL reactor assemblies and magnetic amplifiers, you know complete physical and operating characteristics —a copy of our Catalog R-10 awaits your request. And, delivery is fast because sub-assemblies of these units are stocked, awaiting your control-winding specifications.

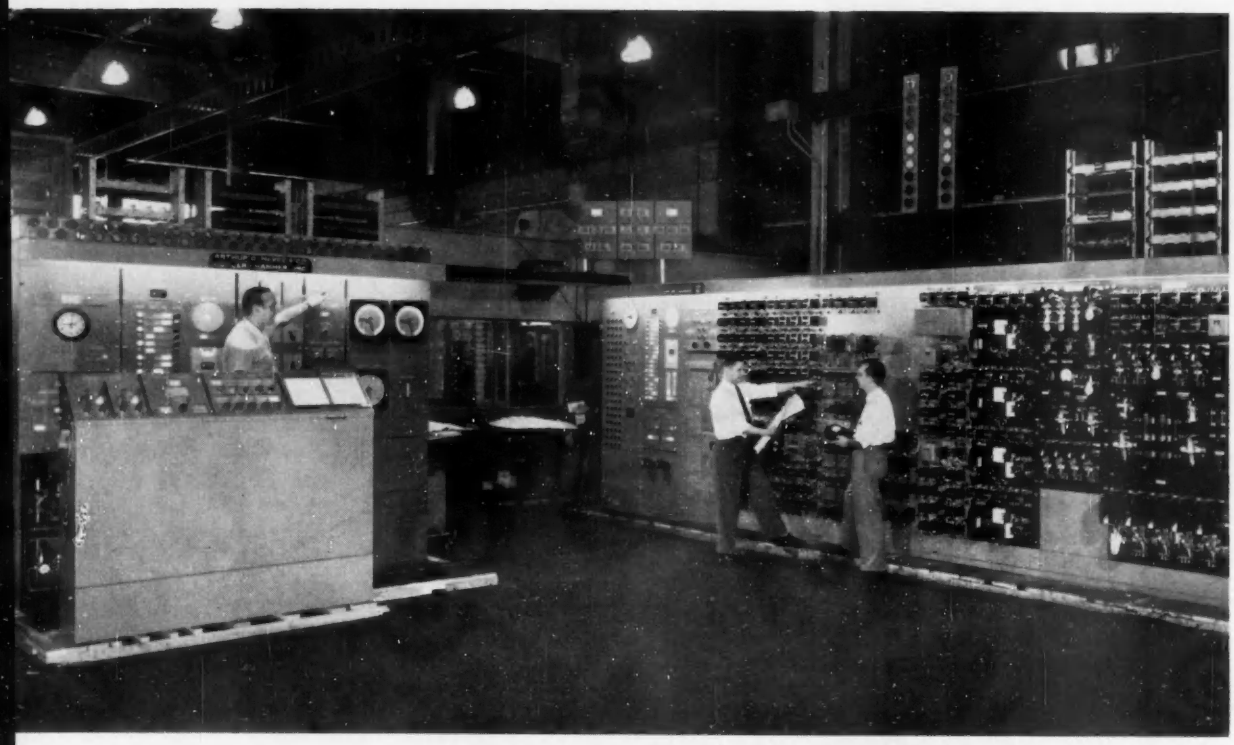
CONTROL reactors are available for both 120- and 240-volt 60-cycle operation. There are eleven standard sizes in each voltage range. They have extremely high gain. Six ampere-turns control nearly 2,000 watts in the largest size. Power outputs range from 50 to 2000 watts, with only 2 ampere-turns required for control of the smallest units.

In addition to higher gain, smaller exciting current, and fewer ampere-turn characteristics, CONTROL reactors have a 40 to 1 cut-off ratio. They are totally enclosed so that the high performance toroidal cores used are protected, and the entire assembly has the ruggedness required for long life.

CONTROL offers the same convenience of standardization in use of high permeability magnetic devices that you've enjoyed with other components. Add to this convenience ruggedness and freedom from maintenance which is unmatched, and you'll welcome CONTROL to your design picture. Write for complete details and literature today. *CONTROL, Dept. CE-36, Butler, Pennsylvania.*

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC.



Brand new panel board control system for blast furnace charging was just developed by Cutler-Hammer, Inc. and Arthur G. McKee & Co. It's typical of the control activity in the steel field.

The STEEL Industry Takes a New Look at Control

Sophisticated controls and the systems-engineering concept are taking the steel industry by storm. They may result in the most dramatic improvements in steel production in 50 years.

Throughout the steel industry, engineers are buzzing about one of the most promising technical developments to hit the business in 50 years. The new concept: automatic-control systems for steel processes.

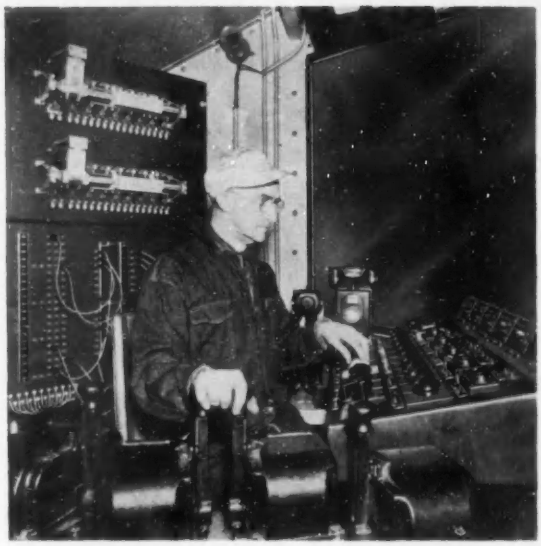
Almost every steel company in the country has some application of sophisticated control under study, under test, or actually in operation. Here are just a few typical ones:

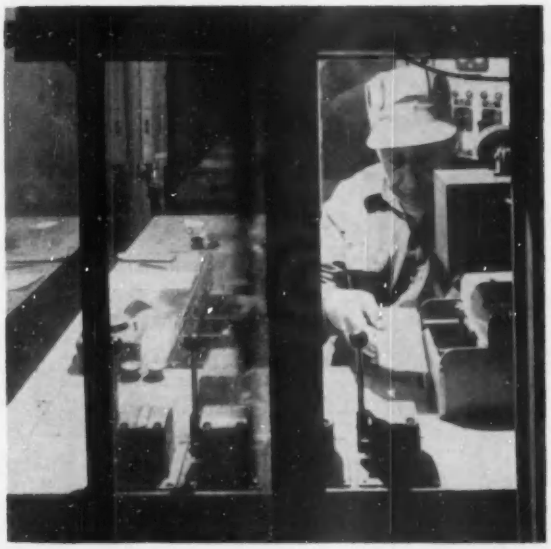
- Card-programmed preset control on a reversing roughing mill, built by GE for Allegheny Ludlum Steel Co.'s Brackenridge, Pa. works, has been in operation for at least six months.
- Card-programmed control for a reversing roughing mill, built by Westinghouse for Jones & Laughlin's Aliquippa Works, was shipped in February, and should start operation later this month.
- Automatic elongation controller, designed and built by Allegheny Ludlum, has been in operation on a single stand mill for six months. It incorporates a computing circuit to measure and control strain during finishing operations.
- X-ray measurement of gage feeds back to control screw-down on cold rod mill at American Steel & Wire's Cleveland works.
- IBM automatic production recording system at American Steel & Wire, Cleveland Works, counts billets entering furnaces and coils of rod leaving the mill, and prepares punched tape for accounting purposes.

Behind this activity are powerful economic forces that are squeezing the steel producing companies. One of these forces is the steadily increasing demand for steel in the face of mushrooming costs of new capacity. A better answer than new plants, the steel companies feel, is bigger production with the same basic equipment. In 1946, steel demand in the U.S. ran about ½ ton for each person. Demand hit ¾ ton for each person last year, and the steel industry estimates that demand will run at the rate of one ton per person by 1975—and the population is increasing steadily.

Still another force is the increasing precision that customers are demand-

FROM JACKS on this first steel mill programmer built by EC&M in 1936 for a screw-down control on a reversing roughing mill . . .





TO CARDS on the automatic programmed reversing roughing mill designed by GE and installed at Allegheny Ludlum Steel Corp. last year.

ing. In the aircraft industry, for example, airframe builders want tighter tolerances on sheet. As one production man explained it, a 10-percent variation on gage—not exceptional in normal rolling—means a 10-percent weight variation that plane builders can't tolerate on new high-speed jet aircraft. And he added, "We're turning out the best quality we can with present controls. It will take some sort of automatic control to do any better."

• **How they do it**—There are three basic approaches that steel companies and control builders are taking:

1. An overall systems approach to the steel-making process featuring complete process integration; this will result in a digital data processor in continuous contact with the variables to optimize steel making.

2. A system approach applied to each major piece of equipment, such as a roughing mill, a blooming mill, a blast furnace, or an annealing line.

3. Adoption of new control devices to steel-mill equipment on a piecemeal basis.

GE urges process integration

One control builder, GE, advocates the overall systems approach. It feels that it's part of the natural evolution of control. The steps: add regulation of electrical machinery; add regulation of process variables; add programmer for automatically setting up and programming the process; add automatic recording of process parameters; and finally, close the loop from the output of the data processor to the input of the programmer with a computer.

What GE likes to do is start with equipment near the end of the production line, improve the controls, and then work back. By studying the machine ahead, improving its controls, GE feels it can reduce the requirement for control on the machine behind. For example, the company feels that many of the problems of cold-mill control stem from quality difficulties in the product from the hot mill. So it studies the hot mill to improve quality of the output. It finds that some of these problems stem from the heating furnaces that precede the hot mills, so then it studies these. And the study proceeds backward to the start.

• **Hunt for data**—One serious deterrent to GE's system integration is the paucity of available data on the dynamics of steel-making processes. GE has put a team of engineers into the field to study steel-making operations with an eye to gathering data that will be useful in designing controls.

To-date, GE hasn't completely sold its integrated approach to any steel company. However, these advanced control projects are underway for GE customers:

• Program control of the screw-down on a blooming mill.

• A structural steel-mill control that uses five different card readers to control 23 individual positioning or speed-control operations.

• A card-program control for at least one roughing mill, with several more in prospect.

• Special steel-mill-control devices, such as pinhole detectors, edge-register-control systems and tinplate-coating condition-inspection apparatus.

Westinghouse, on the other hand, feels that the systems approach to one particular part of the process is the best method of attack at the present time. It reasons that this is the most practical way to start the new control concept, and to gain experience putting a system together and getting it to work.

• **Three Westinghouse systems**—The company has three separate systems that have been engineered for steel- or aluminum-mill application:

The card-programmer control for a roughing mill has been publicized widely. Westinghouse has already sold six of these units.

Westinghouse automatic radiation gage controls have been incorporated

first in Performance Reliability and Quality

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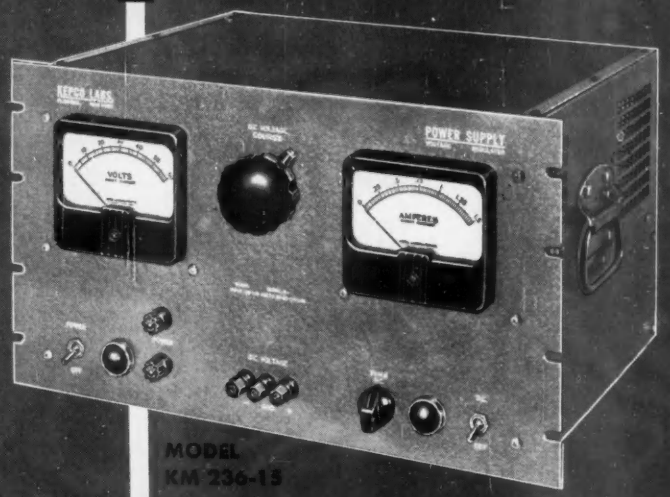
introduces the first in a series of

NEW MAGNETIC TUBELESS VOLTAGE REGULATED POWER SUPPLIES



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2-36 VOLTS 15 AMPS.

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- **Output voltage within 0.5% during recovery time for line transients 105-125 volts.**
- **Short circuit will not damage supply.**
- **Full current may be drawn at any voltage from 2-36 volts.**

OUTPUT VOLTAGE DC: 2-36 volts continuously variable.

OUTPUT CURRENT DC: 0-15 amperes continuous duty.

REGULATION: In the range 2-36 volts the output voltage variation is less than 0.5% for line fluctuation from 105-125 volts, and less than 0.5% or 25 millivolts, whichever is greater, for load variations from minimum to maximum current.

RIPPLE VOLTAGE: Less than 0.5% or 25 millivolts RMS, whichever is greater.

FUSE PROTECTION: Input fuses on front panel.

OVERLOAD PROTECTION: An automatic current limiting device allows direct shorting of the output terminals without damage to the supply.

POWER REQUIREMENTS: 105-125 volts, 57-63 cycles.

OUTPUT TERMINATIONS: DC terminals are clearly marked on the front panel. Either positive or negative terminal of the supply may be grounded. DC terminals are isolated from the chassis. A binding post is available for connecting to the chassis. All terminals are also brought out at the rear of the chassis. Two terminals are mounted at the rear of the chassis to provide for picking up the error signal directly at the load. This connection compensates for the voltage drop in the wires connecting the power supply to the load.

METERS: Ammeter: 0-15 amperes, 4" rectangular.
Voltmeter: 0-15 volts, 4" rectangular.

CONTROLS: Power on-off switch, DC on-off switch, remote error signal on-off switch, coarse and fine voltage controls.

PHYSICAL SPECIFICATIONS: Rack panel construction. Panel height 12¼", width 19", depth 17". Color Kepco standard gray hammertone. This unit is designed for relay rack mounting or bench use. Carry handles are provided.

OPERATIONAL CHARACTERISTICS: This regulated unit consists of a ferro-resonant line regulator followed by a magnetic amplifier regulator. The ferro-resonant line regulator furnishes well regulated transient free AC power. The high gain magnetic amplifier is used to regulate the DC output voltage to compensate for voltage changes in the power unit for varying load currents. The response time for pulse loads is less than 0.2 seconds.

WRITE FOR SPECIFICATIONS ON 30 AND 50 AMP. MAGNETIC SUPPLIES.

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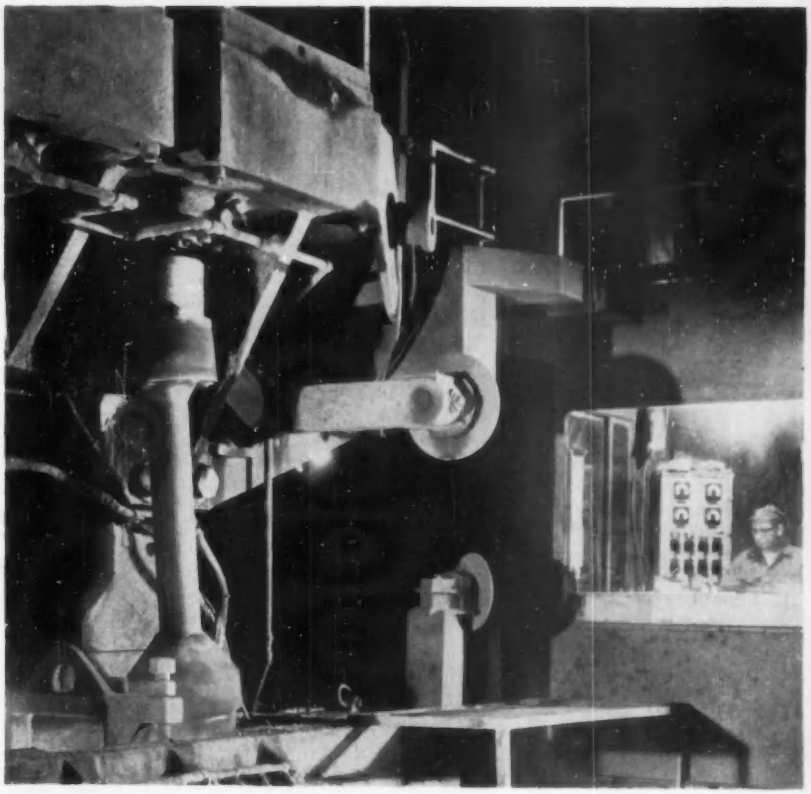
on cold-strip mills in one steel plant and two nonferrous metal installations.

Automatic charging controls for blast furnaces have been available for several years. The most recent innovation is the use of Cypak static-switching devices in them.

Westinghouse control engineers predict that some day the "punched card" will run a steel mill. It will do everything from programming blast furnaces and rolling mills, to adding up the pay of workers.

• **First with jacks**—The early bird in steel mill programming was E C & M (Electric Controller and Manufacturing), now a division of Square D Co. E C & M installed the first mill programmer in 1936 and it is still operating—programming the screw-down of a reversing roughing mill. With this early equipment, an operator initiates each pass of the step-by-step regulation, using a single push button to control side guides, horizontal, and vertical rolls. At the same time, the operator controls rotation of the rolls with a foot pedal.

That pioneering installation was programmed with jacks. Since then E C & M has improved the design, and today programming is done by both circuit panels with adjustable slides and plastic punched card. Currently the company, specializing in screw-down programmers, has orders for seven installations.



GE designed card programmer controls reversing roughing mill at Allegheny Ludlum.

Steel takes the initiative

Control manufacturers will tell you that the steel industry has been quick to take makers' word that these new control devices will work. And, steel producers are doing some first-rate engineering on their own. Among the names behind these developments are R. Holman at U. S. Steel, Orville Orbom at Allegheny Ludlum; Carl Zimmerman at American Steel & Wire's Cleveland Works; Leo DiFiore of Youngstown Sheet & Tube; and R. W. Barnitz of Jones & Laughlin. Industry observers feel that specialty-steel producer Allegheny Ludlum Steel Corp. is probably leading the pack.

A task force headed by Orbom is spearheading control development work at A-L. This group has developed a master plan of action based on a study of steelmaking equipment. They're implementing this plan by using the systems approach on various stages of the process.

• **Framework**—Under A-L's plan, certain specific ground rules have been established. All further systems work has to abide by these ground rules. Orbom points out that sometimes the easiest way to do something specific on a machine can't be done because it clashes with the basic concepts of the master plan. But he claims a master plan is a "must" to keep from succumbing to the temptation of installing gadgets and gimmicks on equipment.

A-L's program for control-systems engineering has three main facets:

1. An analysis of the whole system in terms of the independent and dependent variables.
2. An integrated design of instrument, process reaction, and control.
3. The fabrication and testing of the control hardware.

Orbom says the key to this coordinated automation program is a common-language communication network. "The language must be intelligible not only to men but to machines, electronic mechanisms, automatic inspection devices, and production record generating equipment."

When A-L's automation program gets in high gear, there will be at least five steps to every operation.

• Identification—The input card will carry identification information pertinent at this stage of processing.

• Control—The input card will be read to tell the machine how to set itself up and what product is desired.

• Record—An output card will be punched automatically, identifying the actual product, and a typed output will also be produced.

• Subsequent control—The output card will be passed on to the next operation to provide information to make a new input card.

• Evaluation—The output card can subsequently be processed through computer equipment to provide yield, quality, and cost information, including such important items as down-time and roll-life records.

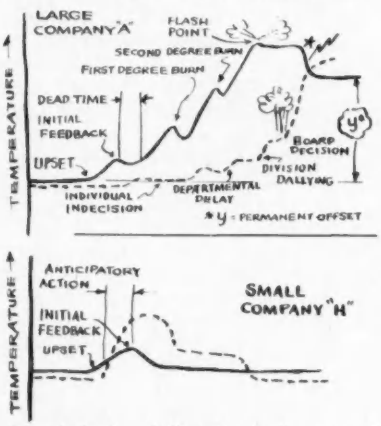
So far A-L's task force is batting a thousand: its one try has resulted in a successful automatic elongation controller on a rolling mill. (The card-programmer for the screw-down of a reversing roughing mill at A-L was designed by GE). The elongation controller is working better than expected and has been received enthusiastically by A-L's Production Dept. But the best may be just around the corner. Orbom's group is

RAMBLINGS ON INSTRUMENTATION

Small—but ferocious!

In all the recent palaver about the beauties of Bigness as a corporate asset, nobody but nobody seems to be going to bat for the many advantages of Smallness . . . or even Medium-Sizeness. Nevertheless many smaller companies offer specific built-in advantages that make them as indispensable to the corporate giants as a tugboat to the Queen Mary.

In volatile fields like instrumentation and automation, the smaller company often offers a real premium in speed, service, and the concentration of high-calibre brainpower that can be brought to bear on a given problem. Un-insulated by layers of corporate fat, unable to bury its mistakes in a labyrinth of multi-divisional rabbit tracks, the smaller company is extremely sensitive to customer needs. In an outfit the size of Hays, for example, there is ferocious personal involvement in the destiny of every job. This rebounds to the advantage of our customers. And in tangible enough terms so that several of our Big-Company customers tell us they wish they could duplicate our agility (if not our volume).



Science lurches forward! Charts above show how customers' under-the-collar temperatures (black line) respond to company action (dotted line).

Here's an example of agile small-company service, lifted from the files of the firm whose bounty sponsors these monthly ramblings. On a recent Friday afternoon our intercom crackled with an urgent call from our Detroit representative. A boiler had burst in a plant of one of the king-size corporations in his territory. Another boiler had been shut down, pending discovery of the cause. Production, in king-size quantities, was being lost. Could we . . . ?

Two of our top engineers were at the scene within hours. Working all through the week-end, they located the trouble (which did *not* involve instrumentation), eliminated it and had the boiler in service at 8 a.m. Monday.

Not a particularly unusual case, either with Hays or many companies our size. But one that accentuates the positive about the advantages of small company service.

The Condu-Therm (adv.)

If, despite our blandishments, you remain somewhat less than fascinated by our ever-popular Hand Orsat . . . if even our chemical CO_2 analyzer leaves you unmoved, why not take a sporting look at our thermal conductivity type analyzer? We call it the Hays Condu-Therm (get it?). While there are many versions, we are rather partial to the Hays design.

For one thing, we enclose the measuring resistors in glass, a microscopic process about which we told you a couple of months back. This causes us no end of trouble, but it does prevent the platinum resistance wire from being oxidized and eliminates a maintenance headache. This, together with a corrosion-proof internal coating, provides a corrosion-resistant surface to troublesome gases.

Another thing: we can supply the Condu-Therm with a saturator, a gimmick that presents the analysis on a constant automatic saturation basis to compensate for the varying water vapor content of the sample.

All in all, a worthy instrument, proved in over 10 years and a few hundred installations. For the facts, write for bulletin 56-1008-59.

Phil Sprague Jr.

President

(Ed note: Regular readers will be pleased to note that Mr. Sprague is now a president without a vice.)

THE HAYS CORPORATION • MICHIGAN CITY, INDIANA

WHAT'S NEW

STEEL

Story starts on page 22

readying a control for a Sendzimir Mill that could revolutionize the sheet steel business.

• **Four basic problems**—After analyzing rolling operations A-L found four basic problems that make it difficult or impossible for present-day rolling mills to guarantee the gage of sheet material. The company thinks it may have found solutions to all four; two of these are already in the hardware stage and being tested; two others are being converted from theoretical solutions to hardware. If A-L is right, this control will permit a mill to turn out gage with a guarantee of ¼ commercial tolerance—something generally unheard of today.

• **Big steel looks ahead**—At U. S. Steel, Holman shows some significant statistics to tell why his company is interested in automatic controls. As he explains it, an increase of only 0.1 percent of "on-spec" material from a 10,000-ton-per-day rolling mill will save 10 tons of steel a day—steel that costs from $105-175 per ton.

To bring about such savings, big steel has preferred to adapt new control devices to mill equipment rather than use a systems approach. And, it's turned out some unusual examples of sophisticated control:

• Automatically controlled sintering plant at the Fairless Works.

• A "Ferrostan" tinplate inspection and control device designed to check the surface of plated sheet at the Irvin Works.

• An x-ray-controlled cold tandem mill with controls built by GE.

• At the Gary works, an adjustable voltage control for dc drives on a four-stand cold tandem mill, which is considered the highest production mill in the steel industry.

• **J&L's progress**—At Jones & Laughlin Steel Co., installation of a card-programmer for a reversing roughing mill is almost completed. Chief

Electrical Engineer R. W. Barnitz will tell you that his company is waiting to see how well the new system works before plunging any deeper. But J&L has already ordered a similar control for a mill in its Cleveland plant. And Barnitz and Assistant Chief Engineer George Kaufman are figuring new ways to use the system.

Despite expressed caution on automatic controls, J&L can visualize a widespread use of such devices throughout steel mills. One thing it thinks will follow shortly: adding information to the punched card at the hot mill, including rolling temperature, gage, and exact width, so that the card serves as a record of a particular batch of steel.

Looking further into the future, J&L's chief electrical engineer sees another steel-mill operation that should be a prime target for computer control. That's automatic control of an open-hearth furnace to eliminate "off heats". "It seems to me," he says, "that computer control, constantly measuring the variables and changing them to fit an optimum standard, would be the answer. But that's a long way off, I'm afraid."

• **The obstacles**—That's a tip-off to some sticky problems that have to be solved by both steel-mill users and control manufacturers. One of the biggest is obtaining detailed information on the dynamics of steel-making.

Still another problem is one of equipment maintenance. As Barnitz says, "This is a new breed of cat for steel-mill maintenance men, and we have to bring our maintenance men along in steps."

In general, steel-mill maintenance crews haven't taken to electronic gear. They've been reluctant to tackle servicing such equipment. But proofs of the fact that this inertia is dissolving are the installation of radiation-gage controls that are basically electronic, and the growing use of electronic induction heating units.

• **Reliability bug**—Still another problem is the old one of reliability. There's still some feeling in the steel industry that electronic gear can't stand the gaff of rough, steel processing. Not so, says A&L, whose elongation controller uses electronic gear with plenty of tubes: "The secret is using them in the right way." According to Orbom, as long as electronic tubes are used in on/off circuits that fail safe, there's no real problem with the tubes. However, you can get into trouble if the operation of the control circuit depends on the characteristics of a tube.

A&L has one other fact to offer in the reliability argument. The electronic gear in its elongation controller has run almost 5,000 hours without a tube failure.

SIZES 11, 15, 18, SYNCHROS & SERVO MOTORS

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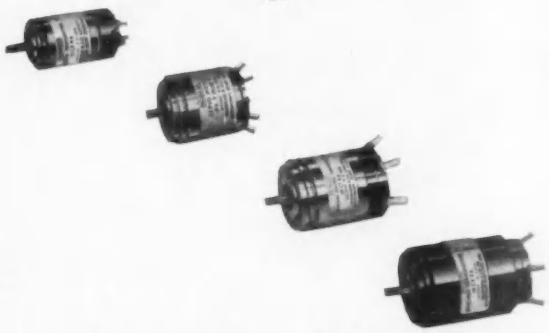
SYNCHROS & SERVO MOTORS MADE STRICTLY TO U.S. MIL SPECIFICATIONS AVAILABLE FOR IMMEDIATE DELIVERY



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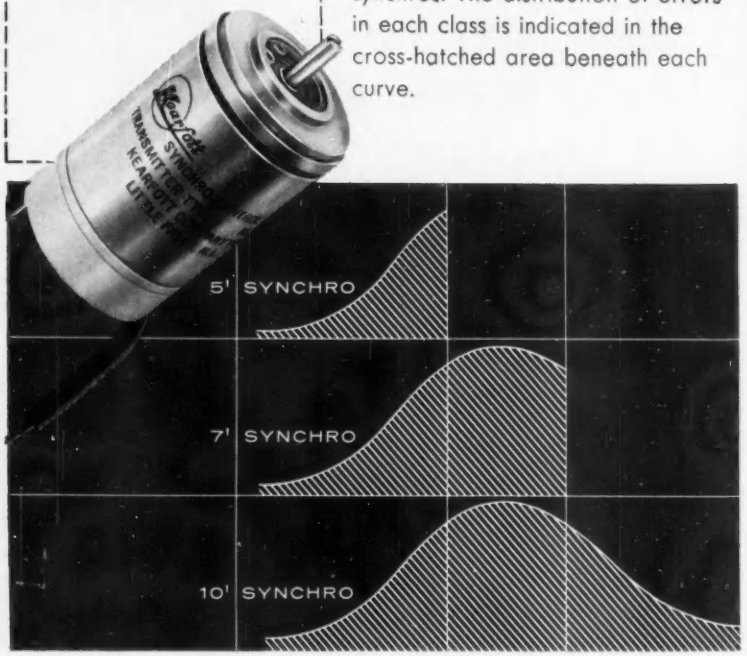

Kearfott Series R900 Synchros are characterized by high accuracy, corrosion resistance and new high temperature stability. Units available for early delivery.

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TRAINING:

Control engineers will have plenty of opportunity to pursue their specialties in a variety of college short courses this summer (see chart, right), a CONTROL ENGINEERING survey indicates. Announcements of the programs listed in the chart were received in answer to a questionnaire mailed to colleges.

For the second straight year, Case will offer Prof. Donald P. Eckman's three-week sessions on process theory. Using concentrated doses—each week includes 10 lectures, four laboratory periods, and eight discussion periods—Eckman and his assistants cover new concepts of automatic control in the process industries, including data processing, computer control, and information theory. One portion of the course stresses developments in components.

University of Michigan is offering two courses in automatic control and five in computing engineering and application: both cover introductory and advanced levels. The first course in automatic control stresses fundamentals of measurement, communications, and control, including basic work on nonlinear systems, the second, the application of the fundamentals to advanced problems.

MIT offers two high-level courses of special interest to control engineers. One covers the systems aspect of digital data processing, emphasizing factors which influence specifications for data conversion devices, and engineering analysis and evaluation of a variety of conversion devices. Considerable use will be made of case histories to illustrate major points.

The second MIT course is an advanced survey of recent developments and specialized techniques in the field of chemical analysis.

Back again this summer are such well-established courses as the Appalachian Gas Measurement Short Course at the University of West Virginia and the Pennsylvania State University seminar on Automation (see p. 30 for full details). For the 17th year, West Virginia will play host to representatives of the gas and petrochemical industries, stressing for three days fundamentals of gas measurement including both instruments for measuring and devices for control.

Wayne State University's Computation Lab is offering a repeat on the computer studies that were so popular last year. This is the fifth year that Wayne will offer summer short courses in computer applications.

Summer Courses Lure Control Engineers Back to Campuses

SCHOOL	COURSE	DATES	FEES	ADDRESS FOR APPLICATIONS	REGISTRATION DEADLINE
CASE INSTITUTE OF TECHNOLOGY	**Process Control Theory** Principles and theory of automatic control with applications to industrial process control.	1st Section: June 10-28 2nd Section: July 15-Aug. 2	$425.00	Donald P. Eckman Mechanical Engineering Dept. Case Institute of Technology 10900 Euclid Avenue Cleveland 6, Ohio	1st Section: April 26, 1957 2nd Section: June 7, 1957
CORNELL UNIVERSITY	**Fundamentals of Feedback Control Systems** Principles of performance from equations and transfer function plots.	July 29-Sept. 14	$133.25	E. M. Strong Director of Co-Op Program School of Elec. Eng. Cornell University Ithaca, N. Y.	None
ILLINOIS INSTITUTE OF TECHNOLOGY	EE 320 Electronics	MWF: 6:20-8:00 pm	$56.00	Registrar Illinois Inst. of Tech. 3300 S. Federal Street Chicago, 18, Ill.	June 19, 1957
	EE 322 Electronics Laboratory	MWF: 8:10-9:50 pm	$42.00		
	Mech 302 Fluid Mechanics	MWF: 6:20-8:00 pm	$56.00		
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	**Analog-Digital Conversion Techniques** Systems Aspects of Digital Data Processing.	Aug. 12-16	$175.00	Office of the Summer Session Room 7-103 Mass. Inst. of Tech. 77 Massachusetts Avenue Cambridge 39, Mass.	None
	New Developments in Instrumental Analysis Survey of recent developments in the field of instrumental chemical analysis.	Aug. 26-30	$175.00		
UNIVERSITY OF MICHIGAN	**Course I Automatic Control** Fundamentals in the field of measurement, communications and control.	June 17-22	$125.00	Prof. L. L. Rauch Room 1521 East Engineering Building University of Michigan Ann Arbor, Mich.	April 15, 1957 (CtE, April, p.42)
	Course II Automatic Control Application of fundamentals to advanced problems.	June 24-26	$60.00		Until course is filled
	Introduction to Digital Computer Engineering	Aug. 19-30	$200.00	Coordinator of Engineering Summer Conferences 2038 East Engineering Building Ann Arbor, Mich.	
	Advanced Digital Computer Engineering	Aug. 19-30	$200.00		
	Introduction to the Electronic Digital Computer and its Application	Aug. 19-30	$200.00		
	Applications of Advanced Numerical Analysis to Digital Computer Problems	Aug. 19-30	$200.00		
	Application of Logic to Advanced Digital Computer Programming	Aug. 19-30	$200.00		
NORTHWESTERN UNIVERSITY	**Transport Properties of Gases at High Temperatures and Pressures**	Aug. 26-28	(Not determined yet)	Ali Bulent Cambel Dept. of Mech. Engineering Northwestern Tech. Inst. Evanston, Ill.	None
UNIVERSITY OF OKLAHOMA	**Automatic Control in the Petroleum and Chemical Industries**	April 29-30		Charles E. Hays School of Elec. Eng. University of Oklahoma Norman, Okla.	None
WAYNE STATE UNIVERSITY	**Introduction to Computers and their Applications** Basic ideas of computers and their components	June 3-8	$125.00	Arvid W. Jacobsen Computation Laboratory Wayne State University Detroit, Mich.	June 1, 1957
	Data Processing in Business and Industry Feasibility studies and methods of initiating electronic programs	June 10-15	$125.00		
	Industrial Management Computer Applications Numerical and programming techniques for the solution of problems	Sept. 9-14	$125.00		
WEST VIRGINIA UNIVERSITY	**Gas Measurement Short Course** Fundamentals of gas measurement, meters, automatic control instruments, and other related equipment.	Aug. 26-28	—	R. E. Hanna University of West Virginia Morgantown, W. Va.	None

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Accurate, Fast Acting, Frequency Type Telemeter for Transmission over Wire Lines, Microwave, and Power Line Carrier

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The Model 1025 Telemeter Transmitter converts DC mv from thermal converters, etc., to 10-30 cps which frequency modulates a built-in audio tone channel. AC 10 to 30 cps or relay outputs are also available. Receiver detects and demodulates transmitted signal, generating a DC mv for operation of recorders or indicating instruments. Up to 45 telemeters can be multiplexed.

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WHAT'S NEW

Third Penn State Seminar Stresses Practical Production Control

In the past three years, Pennsylvania State University's Automation Seminar has earned a reputation for being a down-to-earth session for a practical-minded audience. The 1957 seminar, scheduled for June 9-14, is aimed at continuing that reputation.

Heading up the seminar for the third straight year is Penn State's Chester Linsky, assistant professor of industrial engineering. It's Linsky's belief that the people who attend the seminar are seasoned engineers, experienced in production and most interested in how they can use the new developments of automatic control in their own operations.

The program (see below) reflects this philosophy. Heavy emphasis is being placed on the application of basic criteria related to: planning, design, and installation of automated equipment for in-process transfer, small-parts handling and positioning; automatic-control systems—pneumatic, hydraulic, mechanical, electrical, and electronic; punched tape positioning, and static switching.

Sessions each day are divided into two phases. Each morning is devoted to the presentation of technical papers, each afternoon to workshops where participants get a chance to solve specific problems in control.

For CONTROL ENGINEERING editors, there's a moral in this year's seminar:

THE PENN STATE PROGRAM

TECHNICAL SESSIONS

MONDAY MORNING
Chairman: George G. Karian, F. J. Stokes Corp.
I. The Systems Approach to Automation
A. F. Maynard, General Electric Co.
II. Developing and Presenting Project Proposals and Cost Estimates
Frank Foley, General Electric Co.

TUESDAY MORNING
Chairman: L. T. Ohmart, Armstrong Cork Co.
I. Automating Similar Parts
Jerome Sands, Stromberg Carlson Co.
II. Miniaturization and Small-Parts Handling
Don Zierk, The Elgin National Watch Co.

WEDNESDAY MORNING
Chairman: R. V. Higdon, Haller, Raymond, & Brown, Inc.
I. Packaging and Materials Handling Equipment Design
W. C. Allen, Westinghouse Electric Corp.
V. J. Eichenlaub, Westinghouse Electric Corp.
II. Designing for Automatic In-Process Inspection
L. O. Heinold Jr., Federal Products Corp.

WEDNESDAY EVENING
Panel discussions
I. Problems We Have Had to Face in Operating an Automation Program
Chairman: Herman Melzer, Sylvania Electric Products, Inc.
II. Our Experiences with Acquiring, Training, and Up-Grading Operating Maintenance and Design Personnel for Automation Programs
Chairman: J. S. Wilford, "Production" Magazine.

THURSDAY MORNING
Chairman: B. K. Ledgerwood, CONTROL ENGINEERING
I. Problems in Automatic Control Systems Design
L. A. Horchos, International Business Machines Corp.
II. Design and Operating Features of Tape Controlled Apparatus
W. F. Jessup, Cincinnati Milling & Grinding Machines Co.

FRIDAY MORNING
Chairman: A. S. Marburger, Sperry Rand Corp.
I. Using Present Facilities and Standard Components to Automate Production
Eric C. Brodin, SKF Industries, Inc.
II. Debugging New Equipment
J. J. Williams, Talon, Inc.
III. The Designer's and Operator's Experience with Automated Equipment
E. N. Lenk, Western Electric Co.

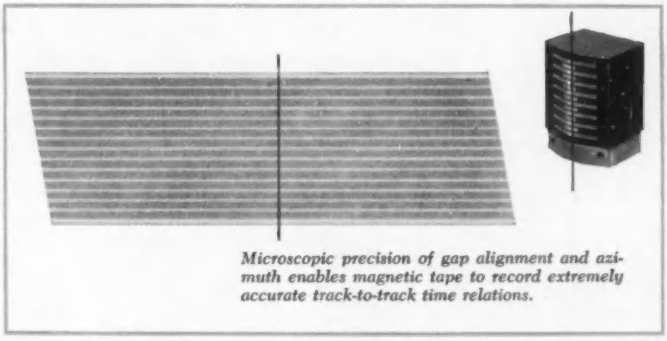
WORK SHOPS

I. Fundamentals of Automation Development
II. How to Develop Project Proposals and Cost Estimates
III. Design of Automatic Feed and Positioning Devices
IV. Design of Special-Purpose Assembly Equipment
V. Fundamentals of Automatic-Control Systems Design
VI. Static Switching Devices
VII. Advanced Automatic Control Systems Design
VIII. Tape and Numerical Machine Tool Control Systems Design
IX. General Bull Session on Automation Problems

How many microseconds apart is "almost simultaneous"?

Here is how magnetic tape gets the answer

When things happen in the front of a jet engine, other occurrences in the rear follow in a flash – no pun intended, we mean in a fraction of a millisecond. Those who test jet engines have found that magnetic tape recording can be used to make a *milli*second look enormous – and to show even fifteen *micro*seconds as a significant interval. Transducers in key points in the front and rear of the engine feed parallel tracks on the tape. The amount of offset between parallel signals provides a measure of their relative timing.



Microscopic precision of gap alignment and azimuth enables magnetic tape to record extremely accurate track-to-track time relations.

For time correlation the head stacks on an Ampex Tape Recorder are like an "electronic tee-square." All of the gaps are in line within 1/10,000th inch. And gap azimuth is accurate to a minute of arc. Tape moves past the head at speeds up to 60 inches per second and multiplies the track-to-track timing accuracy accordingly. (But consult us at Ampex before you rely on simple arithmetical conclusions).

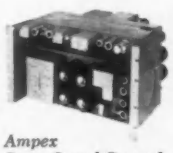
To read these time differences off in measurable form, the tape is reproduced at a small fraction of its original speed (1/32nd, 1/100th, etc. according to machine). It can be recopied onto another tape – be slowed down again – and then be recopied onto a visual recording on which small time intervals are magnified as much as 10,000 times.

If to you this particular example is more spectacular than useful, note that it is only one of numerous talents that magnetic tape has in tying together data and time. Perhaps some of these others fit your needs.

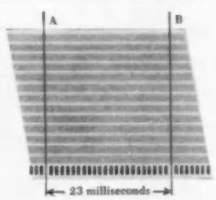
Are you interested in reproducing data in precise real time? Ampex Servo Speed Control can reproduce data with original timing held within two parts in 100,000. It doesn't matter if the tape stretches a little, or if your input power fluctuates from 60 cycles. Servo Speed Control holds a precision signal on the tape in step with a precision time source. At any instant these signals will be in phase within a millisecond or less (depending on tape speed).

Maybe you like your data recordings referred to the time of day. In any of several forms of digital coding, such information fits nicely on a timing track. The time code designates hours, minutes, seconds and even the milliseconds between. Commercial equipment is available for search and control. It can run the tape quickly to any minute and second you designate – handy if your recordings accumulate by tens or hundreds of thousands of feet.

If quick, accurate measurement of time intervals from a fractional second to a few seconds in length are your interest, magnetic tape recordings can make the problem as easy as counting to 1,254,391 . . . on an electronic counter. A series of pulses or sinewave oscillations are recorded on a time track parallel to the data tracks. As many as ten thousand per second can be recorded accurately and reliably. Electronic counting of these pulses measures time intervals to a required precision. There is no strain on your patience or your eyesight.



Ampex Servo Speed Control equipment as used on the FR-100 Recorder.



Electronic counting on a timing track measures time intervals between data

If you are concerned with accurate timing of data and would like to know further of magnetic tape's advantages, we will be glad to furnish additional information. Others of magnetic tape's capabilities will be discussed in this continuing series. Would you like copies mailed direct? Write Dept. HH-3135.

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ONE OF A SERIES 3

Series FR-100

Series 800 Mobile and Airborne

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- small size
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- high frequency stability

Model 3021 Transmitter

An extremely rugged unit designed for high-shock impact and extreme environmental conditions. Subminiaturized and crystal-stabilized.

Frequency Range: 215-235 mc
Power Output: 2 watts
Weight: 1.7 pounds

Write for complete data and prices.

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WHAT'S NEW

Last year, editors criticized the sessions, so Chairman Linsky called on them for help in planning the 1957 program. The result: Managing Editor Byron Ledgerwood chairmans the Thursday morning session and Consulting Editor Harry Mergler conducts a workshop on tape and numerical machine tool control.

Registration fee for the session is $50, which includes all materials. To register, send check payable to Pennsylvania State University to: T. Reed Ferguson, Extension Conference Center, The Pennsylvania State University, University Park, Pa.

New Doctorate Program Starts at U. of Conn.

Electrical Engineering Dept. at the University of Connecticut has extended its program in "Network Theory and Feedback Control Systems" to the doctorate level. It has been offering an MS in this area since 1950. Recent additions in curriculum and research activities make the wider program possible.

United Auto Workers Win Honeywell Engineers

Walter Reuther struck paydirt with his first invasion of the engineering field. Last month, his United Auto Workers won a precedent-setting affiliation election in Minneapolis by a 579-116 landslide as the Federation of Honeywell Engineers voted to join UAW and disaffiliate from the Engineers & Scientists of America. The Honeywell federation represents about 2,000 engineers and technicians at Minneapolis-Honeywell Regulator Co.

The Minneapolis victory represents the start of an ambitious campaign by UAW to organize engineers in the aircraft and guided-missile industry. Early in February UAW set down the organization of engineers as one of its major goals for 1958. Later it announced the formation of an Aircraft & Avionics Engineering Council as the heart of its program.

The big question now is where UAW will go next. Union leaders aren't talking, but one UAW chieftain reported "a number of large important engineering groups have asked UAW for help. We're responding as fast as possible." The same official emphasized that UAW planned an aggressive campaign.

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- rugged
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Model 3052 Amplifier

Provides 50 watts output from 2 watts input. Rugged construction and the use of a stacked ceramic tube makes this amplifier stable and reliable over a wide range of environmental conditions:

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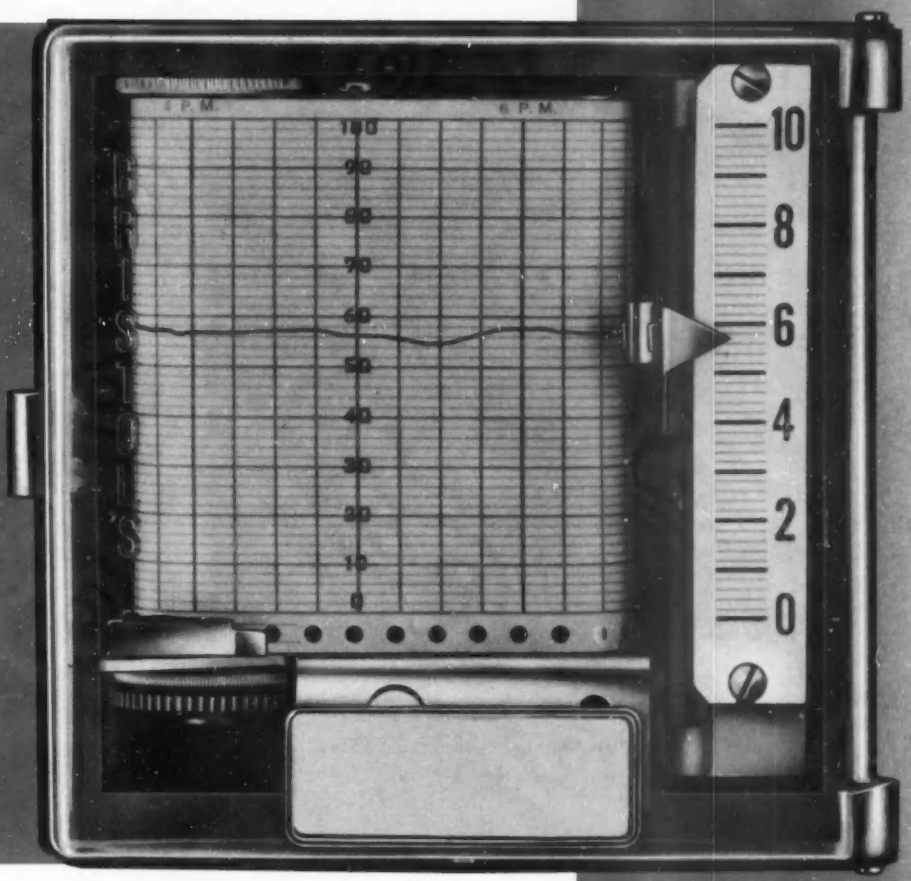
Another BRISTOL First...



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Only 5" x 5⅛", mounts on 6½" centers!

First true motor-driven self-balancing electronic instrument in miniature size!

USES 3-INCH CHART, HAS FULL PLUG-IN FLEXIBILITY!

It's the new Bristol Series 663 Miniature Electronic Dynamaster* Instrument—now available in both indicating and recording models.

No delicate, low-torque galvanometer-type drive unit in this instrument! *The 663 employs motor-driven slidewire self-balancing — the same principle that's been time-proved for superlative accuracy and dependability in full-size Dynamaster instruments.* All in a panel space only 5" x 5⅛"!

With this advance, Bristol steps ahead on two fronts:

1. Bristol now offers the widest selection of miniature plug-in instruments on the market — electronic, pneumatic, and telemetering (all with the same panel cutout) — you can get them all from Bristol.

2. Bristol becomes the first manufacturer to offer both full-size and miniature instruments in a full line. Your instrument problems get unbiased recommendations from Bristol — every time!

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BRISTOL'S
REG. U.S. PAT. OFFICE

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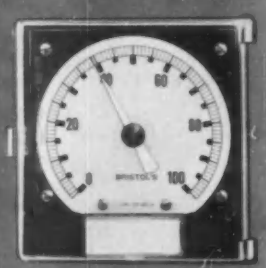

SAME INSTRUMENT
also made as an indicator.
See next page.

Turn the page
for features on this exciting instrument development.

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recording efficiency!

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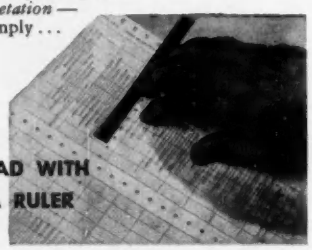
TWO-CHANNEL GALVANOMETRIC
RECTILINEAR RECORDER

Record two variables side-by-side on one chart roll in their true wave forms, and visually correlate to a common time base. The compact *DUAL recti/riter* gives you galvanometer reliability—high deflection sensitivity —0.45 inch/100 microamperes; full scale rise time—0.25 second; AC, DC, spring, or external drives; 10 fingertip chart speed changes; and meter movements of 1, 5, 10, or 25 ma input for full scale deflection.

But most important of all, the *DUAL recti/riter* gives you *easy interpretation* — simply . . .



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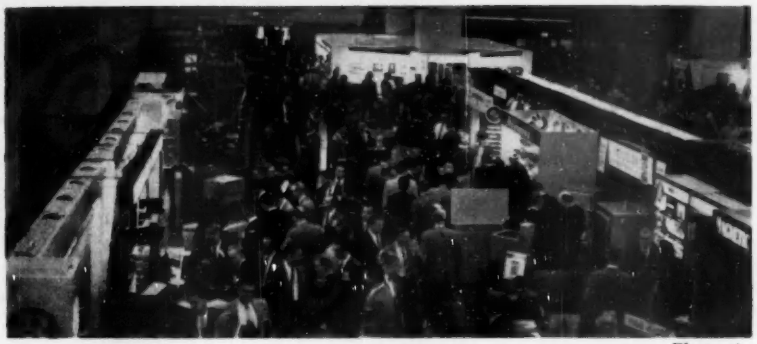


Electronics

Jammed aisles made navigation tough, as . . .

IRE Crowds Shatter Attendance Records

Over 57,000 visitors, an all-time IRE record, poured into New York City's giant Coliseum during the four-day IRE show, biggest in the institute's history. Avid visitors overflowed the more-than-800 exhibitors' booths from the show's opening until it closed, leaving exhibitor personnel limp and exhausted. Only IRE's careful organization of exhibits into four major classes—equipment, components, instruments and controls, and production machinery—each with its own floor, kept the show from turning into a maze of confusion.

Control engineers had a field day picking their way through 132 booths displaying control components, 27 exhibits of systems suppliers, and 12 displays by computer manufacturers, Among the show highlights:

- An automatic analog computer that goes well beyond just automatic pot setting, displayed by Reeves Instrument Co.
- A low-cost remote-positioning device with small input torque and high output torque, shown by Air-Marine Motors.
- An electrohydraulic positioning servomechanism, accurate to within 0.001 in., built by Eastern Industries.
- New magnetically controlled scaler-divider in the booth of Magnetics Research Co.
- Transistorized pulse-programming, equipment exhibited by Navigation Computer Corp.
- Electronic tachometer that counts rpm or frequency, in a plug-in package designed by Standard Electric Time.
- New microwave spectrum analyzer and a new miniaturized sphere resolver, announced by Vectron, Inc.

The Reeves "Auto Control" system prompted a flurry of interest. Reeves delivered its first REAC with the automatic system to the Navy's Project Cyclone at the end of the show. Four more such systems are under construction for Wright-Patterson AFB, and three others have been sold.

With the "Auto-Control" system, automatic cycling commands from a central-control panel produce typed-out readings of all pot settings (including problem-check pots), all amplifiers, or all integrators. A punched tape can program the computer to solve sets of equations by changing pot settings and patchboy connections (via relays) automatically between runs. Servo-function generators are set up away from the computer by preparing plug-in padding turrets.

Technical sessions

For the control engineer, IRE's Professional Group on Automatic Control—a newcomer to the field—prepared two special sessions. Both were led off by outstanding men in control. Prof. J. G. Truxal of Brooklyn Polytech opened the first session with a paper coauthored with E. Mishkin. Their presentation: "Nonlinear Compensating Networks". They covered the general character and practical requirements of such networks and mentioned briefly a few applications.

Most of the authors in the first session represented universities—California, Pennsylvania, and New York University—and gave an academic rather than a practical flavor to the meeting. The final presentation of this session, by Convair's I. Van Horn, "Nonlinear Techniques Applied to the Analysis of Pilot-Induced Oscillations", verified theory by flight test

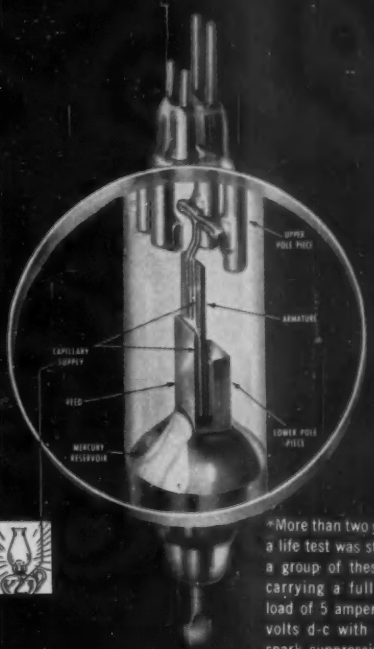
THIS CLARE RELAY IS *practically* FOREVER*

In many applications the right kind of relay will outlast and outperform any other circuit elements.

Even the most eager advocates of static switching systems—where static-magnetic and solid-state elements are used to accomplish functions usually performed by relays and other contact-making devices—now recognize this fact.

The Clare Mercury-Wetted-Contact Relay, for example, has a life of billions* of faultless operations. It requires no maintenance. It can switch from 250 volt-amperes down to a faint whisper of voltage and current. It is the best dry circuit relay in existence. More than that—it is completely free from contact bounce.

THIS is the relay that has become the main reliance of hundreds of leading designers of computing, data-processing and control equipment. For complete information write for Bulletins 120 and 122, C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: 659 Bayview Avenue, Toronto 17. Cable Address: CLARELAY.



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FIRST in the industrial field

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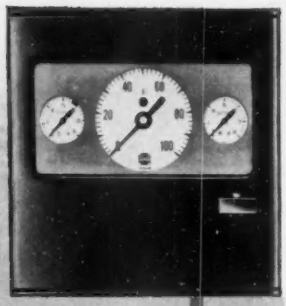
TRANSMITTER
to
RECEIVER GAUGE



unequalled USG®
sensitivity-dependability

There's never a question as to the accuracy of temperature or pressure readings when transmitted by USG Pneumatic Transmitters.

And for accurate reception of signals from remote points, there's nothing to match the sensitivity of the new USG Receiver Gauge.

Consider these features:

USG PNEUMATIC TRANSMITTERS

- Sensitivity—Within 0.1% of full scale.
- Accuracy—1% (indicating) or ½% (non-indicating)
- Designed to operate at remote points for long periods without attention. High sensitivity, linearity and freedom from dead spot assure the ultimate in control stability.

USG PNEUMATIC RECEIVER GAUGES

- Sensitivity—Within 1/10 of 1% of full scale.
- Accuracy—± ¼ of 1% of full scale.
- Diaphragms made of Ni-Span "C", a special high nickel alloy with a minimum thermal shift, even under wide variations in ambient temperature.
- Available in 3½", 4½", 6" and 8½" sizes.
- Also available are 2", 2½" and 3½" Bourdon tube actuated type receiver gauges.

USG Transmitters and Receiver Gauges are part of USG's line of creatively engineered process control instruments. The line includes gauges, pressure and temperature pilots, recorders and controllers. Write for catalogs.

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WHAT'S NEW

and provoked a goodly number of questions.

The second session got underway with a paper by Columbia University's Prof. J. R. Ragazzini on "Digital Controllers". He described designs in which fast response is obtained by making the output-data rate a multiple of the input rate. According to Ragazzini, designs based on simplified-data theory lead to systems whose designs provide a compromise with fast response to ramp inputs but without undue sensitivity to step inputs.

J. J. Kukel, Servomechanisms, Inc., then discussed "Sampling in Linear and Nonlinear Feedback Control Systems". He described an extension of the Z transform in which the Laplace transform and its associated limitations may be by-passed. Kukel said that nonlinear systems can be handled by this approach. C. W. Steeg of MIT outlined latest development in the "Design of Optimum Filters and Predictors" by extensions of the Wiener theory to time-varying systems.

Other papers covered "Solutions of Statistical Problems by Automatic Control Techniques" by R. L. Cosgriff of Ohio State University and "The Role of Automatic Control in the Modification of Aircraft Dynamic Flight Characteristics" by W. M. Turner, Hughes Aircraft Co.

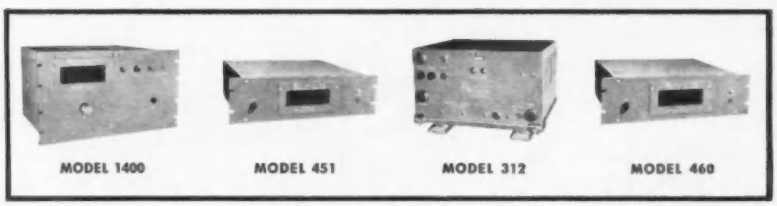
Most of those attending the meetings felt that much of the information presented was new and stimulating. But a feeling persisted that some of the papers were lacking in practical information.

The IRE Professional Group on Automatic Control was plagued by some physical problems. The highly-touted Waldorf Astoria Hotel–site of the control sessions–failed to live up to its storied reputation. Control engineers found their meeting room resembled a long tunnel with bad lighting arrangements. A tight schedule complicated matters too.

Los Angeles Section, IRE

The Professional Group on Military Electronics of the L. A. section, IRE, sponsored a March meeting that put representatives of the military services on the griddle.

The big discussion centered around the charge that military research and development people rely on big business for contract performance. H. L. Hoffman, president of Hoffman Radio and Hoffman Electronics, made a plea



MODEL 1400 Wide Range Voltmeter—Utilizes mercury wetted relays for maximum life and reliability.

MODEL 451 General Purpose Voltmeter—For display or recording of ±0.001 to ±999.9 volts DC.

MODEL 312 High-Speed Voltmeter—For airborne analog-to-digital conversion.

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It's as simple as 1, 2, 3, for even untrained personnel to clearly and accurately make electrical measurements with NLS digital meters. Inch-high numerals are legible from 30 feet away. NLS originated the automatic digital voltmeter and now manufactures a broad range of these and other precise, related instruments for both laboratory and industry. Accuracy, ruggedness, and dependability are proven features of these digital meters for measuring resistance or voltage. Automatic data recording on Clary printer, electric typewriter, card, or paper punching equipment is available. Whatever your need for high speed, completely reliable electric measurement instruments, you'll find your answer in the NLS complete line. Write on your letterhead for the name and address of your nearest NLS representative, who will be glad to discuss your needs, or mail the coupon for full information on these high precision instruments.

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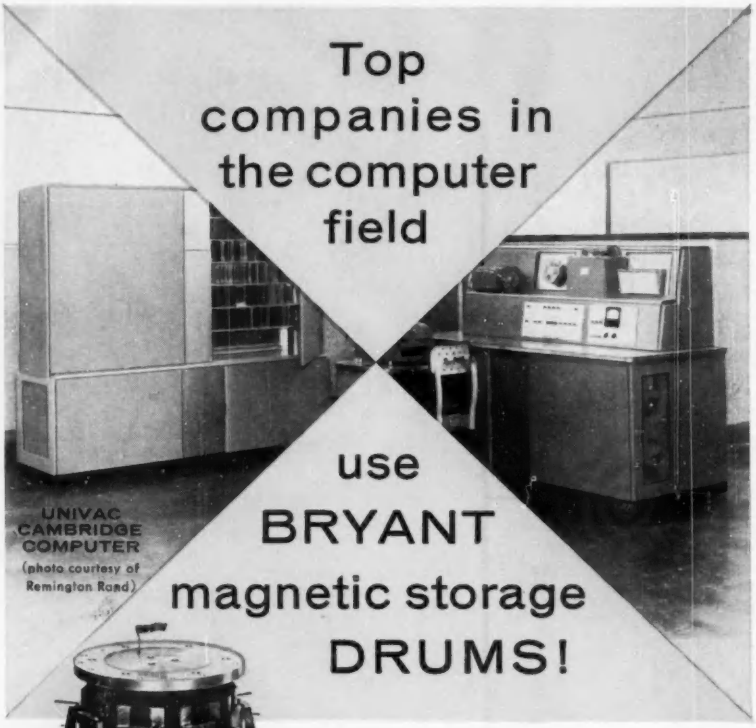

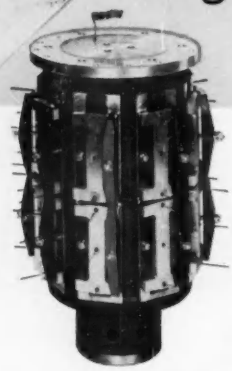

Bryant Magnetic Drums are used extensively by Remington Rand—Univac and other leading manufacturers of electronic computers, because of their accurate, dependable performance. These drums are used not only in digital computers, inventory control systems and tape-to-card converters, but also as delay lines, synchronizers and frequency generators.

FEATURES

- Designed to purchasers' requirements
- Guaranteed accuracy of drum runout .00010" T. I. R. or less
- Air bearings or super-precision ball bearings
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P. O. Box 620-L, Springfield, Vermont, U. S. A.
DIVISION OF BRYANT CHUCKING GRINDER CO.

WHAT'S NEW

for wider distribution of research contracts to "middle-sized" firms. Col. J. E. Johnston, chief, Western Ordnance District, defended the government's activity, pointing out that various-sized organizations were involved in missile-development work.

Other subjects chewed were: specification problems—there was a complaint of too much duplication and too little standardization among the military services; military pressures for early delivery of research and development—several speakers pointed out the difficulty of predicting exact completion dates for research projects. *M.M.*

Reliability talk at . . .

Western Joint Computer Conference

At Los Angeles' Statler Hotel, the Western Joint Computer Conference convened on Feb. 26, 27, and 28. Although the theme "Techniques for Reliability" hit home for computer engineers, operating personnel and systems designers, it apparently dissuaded other professionals from attending, because registration was well below last year's figure.

In the technical sessions, the papers emphasized the systems treatment and new approach to reliability problems. A. W. Boldyreff of the Rand Corp. started the sessions off with a general discussion of reliability from a systems standpoint. His opinion: reliability must be considered as a parameter in systems anaylsis. W. H. Ware, also of the Rand Corp., followed, discussing reliability and computers. He pointed out that analog computers utilize feedback and need be reliable only on the average, but digital systems must have instantaneous reliability.

Several papers of paramount interest to engineers in the process industries concerned methods of improving reliability of computers in control systems. One of these, "Diagnostic Tech-

Three voltage ranges:
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MODEL C-1581M:	125-325 VDC, 0-1500 MA....605.00	MODEL C-1581:	125-325 VDC, 0-1500 MA....575.00
MODEL C-1582M:	325-525 VDC, 0-1500 MA....680.00	MODEL C-1582:	325-525 VDC, 0-1500 MA....650.00

800 MA MODELS **NEED ONLY 7" OF PANEL HEIGHT!**

(metered)		(unmetered)	
MODEL C-880M:	0-200 VDC, 0-800 MA....370.00	MODEL C-880:	0-200 VDC, 0-800 MA....340.00
MODEL C-881M:	125-325 VDC, 0-800 MA....345.00	MODEL C-881:	125-325 VDC, 0-800 MA....315.00
MODEL C-882M:	325-525 VDC, 0-800 MA....390.00	MODEL C-882:	325-525 VDC, 0-800 MA....360.00

400 MA MODELS **NEED ONLY 5¼" OF PANEL HEIGHT!**

(metered)		(unmetered)	
MODEL C-480M:	0-200 VDC, 0-400 MA....289.50	MODEL C-480:	0-200 VDC, 0-400 MA....259.50
MODEL C-481M:	125-325 VDC, 0-400 MA....274.50	MODEL C-481:	125-325 VDC, 0-400 MA....244.50
MODEL C-482M:	325-525 VDC, 0-400 MA....289.50	MODEL C-482:	325-525 VDC, 0-400 MA....259.50

200 MA MODELS **NEED ONLY 5¼" OF PANEL HEIGHT!**

(metered)		(unmetered)	
MODEL C-280M:	0-200 VDC, 0-200 MA....214.50	MODEL C-280:	0-200 VDC, 0-200 MA....184.50
MODEL C-281M:	125-325 VDC, 0-200 MA....189.50	MODEL C-281:	125-325 VDC, 0-200 MA....159.50
MODEL C-282M:	325-525 VDC, 0-200 MA....199.50	MODEL C-282:	325-525 VDC, 0-200 MA....169.50

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INTERNAL IMPEDANCE

C- 200 Series ..... Less than 6 ohms.
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(unregulated) ..... 6.5 VAC (at 115 VAC Input).

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C- 400 Series ..... 15 AMP
C- 800 Series ..... 20 AMP
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AC INPUT .... 105-125 VAC, 50-400 CPS

OVERLOAD PROTECTION.... AC and DC fuses; built-in blown-fuse indicators.

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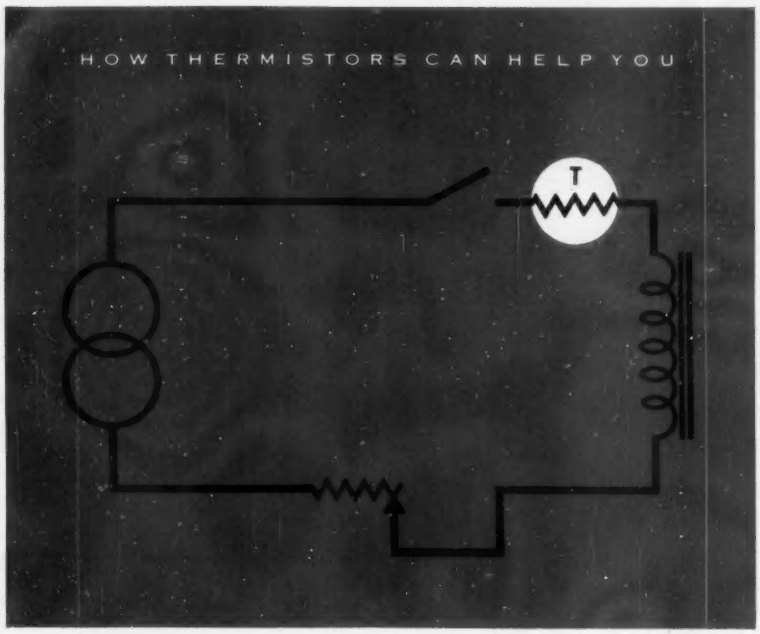
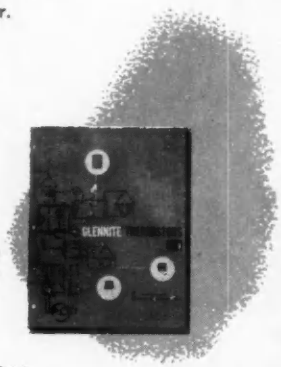


Effecting Time Delay with GLENNITE® Thermistors

An extremely effective time delay can be accomplished using Glennite Thermistors. This method shows distinct advantages over conventional time delay methods because of Glennite Thermistors' small size, long life, ruggedness and the elimination of moving parts.

The Glennite Rod Thermistor in the above schematic regulates current flow resulting in variable or fixed delay due to resistance change in the thermistor. Variable time delay can be obtained from a fraction of a second to several minutes.

Glennite Thermistors are available in bead, probe and wafer units, too — with some units offering temperature coefficients up to 7% per °C.



Complete technical specifications and typical applications are in the Brochure T-100 . . . write for your copy.

FROM RAW MATERIALS TO COMPLETE SYSTEMS . . .

Thermistor Division
Gulton Industries, Inc.
METUCHEN, NEW JERSEY

WHAT'S NEW

niques Improve Reliability", by M. Grahams, R. K. Smith, and W. Statler of Boeing Airplane Co., dealt with programming. The authors reported that routines have been developed to detect errors, automatically record these errors, record other data, take corrective measures, and then continue to operate.

The systems approach appears to be the key to reliability, according to B. K. Smith of Beckman Instruments. In his paper, "The Interpretation and Attainment of Reliability in Industrial Data Systems", he pointed out that system inertia may be used to keep the system under operation during periods of computer failure.

A new and interesting concept was presented by W. E. Smith, Aeronutronic Systems, Inc. He described a digital system simulator in which flip-flops and logical decision elements are represented by coded patterns in storage, rather than by physical circuitry. As computation proceeds, changes are made in the stored patterns in accordance with the program instructions and the stored logic. But this simplification in equipment, said Smith, is attained at the expense of considerably faster computation time. *E.M.G.*

CONTROL BITS

A transistorized-power reactor-control system will be designed and built for the U. S. Navy by Fairchild Camera & Instrument Co. The Navy contract calls for developing components for a reactor power level measuring system that can measure neutron flux from the start-up range throughout the power range.

•

Cryotrons, tiny low-temperature devices, are making news again. Arthur D. Little Co. is using 250,000 cryotrons in an electronic catalog instead of 50,000 vacuum tubes. MIT developer Dudley A. Buck says the device may be able to reduce large-scale digital computers to only 1 cu ft in size. But two big disadvantages loom: 1) the devices can work only at 4.2 F *above absolute zero*; 2) slow speed.

•

A transistorized special purpose analog computer was shipped by Beckman's Scientific Instruments Div. to Baldwin-Lima-Hamilton Corp. for ballistic missile research test stands. Transistors and magnetic circuits replace vacuum tubes for reliability.

Dave Taylor discusses DATA SYSTEMS

Digital measuring techniques, having made possible automatic handling of test data from wind tunnel, engine test and similar applications, have also focused attention on other areas.

Before the advent of digital techniques, most testing was satisfied by analog recording with manual transcription of data for further data reduction. In the majority of cases, each variable was handled as an independent instrumentation channel. Demands for greater precision and accuracy made digital instrumentation desirable. Increase in the number of measured parameters further demanded time-sharing of expensive items of equipment to maintain overall costs within economic limits. The result has been that the problems have become systems problems rather than primarily instrumentation problems.

A simplified test problem may be considered to be the acquisition of data from a multiplicity of transducer elements, representing pressures and temperatures in a digital form, for direct evaluation and in a reproducible form for further data reduction or data processing. Even though techniques and equipment are available for accomplishing the requirements, additional problems arise, which must be delicately handled from the standpoint of overall accuracy. A typical example is the wide range of full-scale values of measured pressures.

Full-scale ranges of pressure measurements may vary from a few inches of mercury to several hundred inches. Transducers operating at 300 inches of mercury may not be used for precision measurements over the range 0-30 inches of mercury because even with an accuracy of 0.1% at the higher range, the error is .3″ Hg which becomes a 1% error in the lower range. With the rapidly increasing cost of transducers for accuracies better than 1%, a decision is required as to the way that cost may be best balanced against overall accuracy. Several solutions are immediately suggested: (1) supply a transducer of the proper range for each pressure; (2) supply a single pressure measuring system with an accuracy approaching .01% of maximum range; or (3) supply several transducers covering portions of the range with automatic selection of the proper transducer. Each of the solutions may offer the same degree of compromise, yet each presents its own inherent problems. A transducer of high accuracy for each pressure can become costly for large numbers of pressures and for required calibration time. A single pressure measuring system of extreme accuracy carries with it attendant switching of pressure lines and likely serious pressure stabilization time, as well as automatic selection complexities. Each solution may be considered equally proper for individual cases. A satisfactory choice of method can only be made in consideration of the overall aspects of the particular problem.

Dave Taylor discusses instrumentation in data handling systems.

It is evident that digitization has brought instrumentation problems into a tightly integrated unit. For improvement of present systems, early digitization of the analog signal is essential. When a truly digital transducer is developed, a completely digital system will be possible. Then new concepts will be applicable and the physical aspects of the measured parameters will become the major limiting factor of the system.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write us.

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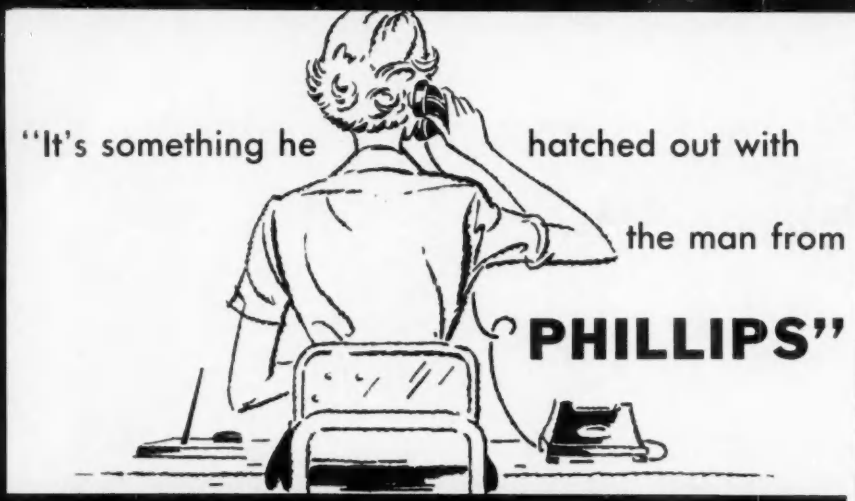

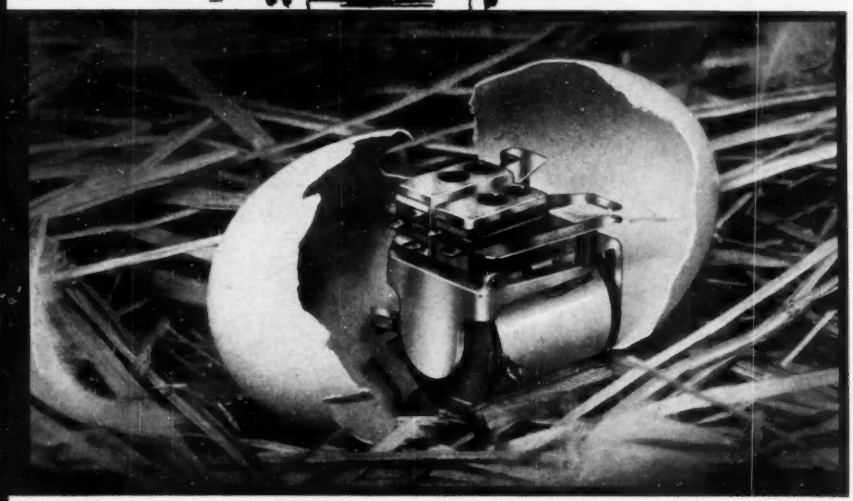

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Resistance: up to 16000 ohms
Single or double wound
Operating time: 0.050 sec., max.
0.003 sec., min.

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All forms A, B, or C
Single or double pile-up
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Other contacts available

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***your* problem hard-boiled?** Type 4C was developed for coddling those requirements of maximum sensitivity and long life in a minimum space. It possesses a highly efficient magnetic circuit operating on a minimum of power. The armature backstop on Type 4C is stainless steel for maximum strength while the armature is fixed to a precision-ground stainless steel pin. A standard Phillips Type 4 contact spring assembly is used, however, all variations in contact arrangements and contact materials are available. Type 4 coils are available single or double wound, with time delay slugs and special windings for high-temperature and/or high humidity.

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WHAT'S NEW

Automatic Testing

. . . reaps unexpected dividends at Westinghouse's Air Arm Div. as transfer of responsibility for decisions from man to machines downgrades skills required for testing.

When Westinghouse's Air Arm Div. was faced with an acute shortage of highly skilled technicians for testing aircraft control systems, the company decided to try automatic testing techniques. After 18 months developing such gear, Westinghouse reaped unexpected dividends:

- ▶ testing time per system was cut from 1,000 to 200 hrs
- ▶ quality, particularly of spare parts, improved significantly
- ▶ labor skill required for testing was down-graded
- ▶ new concepts of job-shop production were developed.

In developing automatic testing equipment, Westinghouse's objective was to transfer the responsibility for making decisions from technicians to machines. A study of their testing procedures showed that five areas were prime targets for action: 1) component testing at incoming inspection and transformer manufacturing; 2) wire-harness checkout at the assembly stages; 3) unit and subassembly testing; 4) major assembly testing; 5) composite testing.

• **Technician grades**—The company uses a system that grades technicians from one to 11. A grade 11 technician is just a cut below an engineer; a grade one technician is at the other end of the scale. Westinghouse was using grade 8 and 9 technicians—almost impossible to hire in Baltimore's tight labor market—for testing before the automatic equipment was developed. After it was installed, the company was able to accomplish all testing using only grade 3 technicians, who were easier to hire and to train. When production tripled, the higher grade technicians were required to service the automatic equipment and to troubleshoot.

Westinghouse invested almost a million dollars in designing and building this gear:

- ▶ Automatic Molded Unit Test Set—makes static and dynamic tests of molded units in quantities.
- ▶ Automatic Turns Ratio—checks the electrical relationship between the

TECHNIQUES and DEVELOPMENTS in oscillographic recording

FROM SANBORN

RECORDING METHOD USED IN SANBORN DIRECT WRITERS, AND A REVIEW OF THEORETICAL AND ACTUAL ERROR FACTORS

Figure 1 shows the basic scheme by which Sanborn oscillographic recording galvanometers produce graphic records of electrical signal values. If the rapid deflection action of the heated ribbon tip stylus is visualized when current flows in the coil, it can be seen that a straight line at right angles to the chart length is recorded on the chart, at the point where the chart is drawn over a knife edge. The trace, therefore, is a true rectangular co-ordinate graph.

Since this is essentially a process of expressing coil (or stylus) deflection *angles* in terms of *distances* on a chart, the trigonometry of the situation (Fig. 2) must be examined to ascertain the accuracy of the method. Initially, and when θ is small, the tangent and the angle are almost equal numerically. The expression $D = R \tan \theta$ can, therefore, be rewritten $D = R\theta$ (approx.). To the extent this latter expression is true, deflection distances (rather than deflection angles) are an accurate measure of signal values. But to determine the extent of error resulting from using this approximation, the following data have been calculated*, using a chart width of 25 mm either side of zero ("D" in Fig. 2) and effective stylus length of 100 mm ("R" in Fig. 2) in the series expansion for the tangent function. Error as a function of deflection then becomes:

FIG. 2

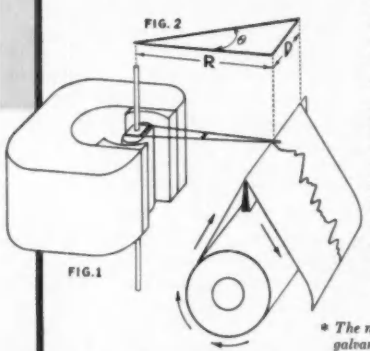

FIG. 1

D mms	Radians	Theoretical Error ϵ	Corrected Error δ	Corrected Error in mms
10	.10	.0033	0	0
15	.15	.0075	.004	.06
20	.20	.0133	.010	.20
25	.25	.0209	.018	.45

When the recording system is calibrated, that calibration is often made on the basis of a one centimeter deflection from the chart center, or by means of a two centimeter deflection starting one centimeter below chart center and finishing one centimeter above chart center. In either case the deflection at one centimeter from chart center is accepted as the standard, and, therefore, is without error. The foregoing table can therefore be corrected by subtracting .0033 from each of the error terms to show the error, δ, to be expected in actual use. The final column in the table shows this error in mms.

Since the active length of the stylus increases as θ increases, deflection D increases more rapidly than θ. All positive error terms in the series expansion bear this out, but the error terms would occur as predicted only if the galvanometer produced deflections exactly proportional to coil currents (that is, ideal spring properties in the torsion rods and uniformity of magnetic field). Pole tips in Sanborn galvanometers are proportioned so that in maximum deflections, galvanometer sensitivity *decreases* slightly, the compensation resulting in *actual* linearity better than that predicted in the table.

* *The mathematics involved here, as well as a discussion of fixed length stylii, design parameters affecting over-all galvanometer performance, etc., are contained in an article by Dr. Athur Miller "Sanborn Recording Galvanometers", published in the May 1956 Sanborn RIGHT ANGLE. Copies are available on request.*

RECOGNIZE A "150" RECORD BY THESE *THREE* FEATURES...

1% Linearity

. . . resulting from use of current feedback Driver Amplifier in *each* channel, high torque galvanometers of new shorted coil frame design. Coil current of 10 ma develops 200,000 dyne cm torque, sensitivity is 10 ma/cm deflection.

Rectangular Coordinates

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Permanent Inkless Traces

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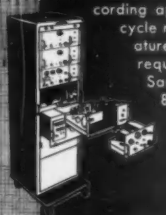

Call on Sanborn engineers for help with your oscillographic recording application in the 0-100 cycle range. Descriptive literature is also available on request, providing data on Sanborn 1-, 2-, 4-, 6- and 8-channel Systems, choice of 12 interchangeable plug-in Preamplifiers, Separate and Supplementary Instruments.

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WHAT'S NEW

number of turns in any transformer of multiple windings.

▶ Automatic Computer Test Stand—Sets up various input parameters to establish whether the computer can do flight problems satisfactorily.

▶ Automatic Cable Harness Checker—checks each wire to make sure it is connected to the right point, then proceeds to hi-pot every wire.

▶ Automatic Function Tester—makes continuity, leakage, resistance, impedance, ac and dc measurements at a rate of three tests a second.

▶ Potentiometer Checker—makes 50 checks of resistance (to 0.05 percent per exact angular position) on ganged precision potentiometers.

Almost as impressive to Westinghouse executives as the time savings was the improvement in quality that resulted from the use of the automatic equipment. As S. W. Herwald, manager of the division, put it, "Men can make mistakes, machines don't." Westinghouse found that computers were coming up to final inspection with as many as 50 errors in them, despite 1,000 hours of inspecting by high-grade technicians. Now the faults average two per computer.

• **Branching out**—Among the new ideas that Westinghouse management is chewing over as a result of this program is the extension of automatic techniques to production—even the job-shop types of operation. The engineers who developed the automatic test equipment have been shifted to the study and design of numerical control for machine tools. First step: control of punch presses and drill presses used to fabricate chassis.

Still another idea that seems promising is the extension of automatic testing techniques to field service. Herwald pointed out that the armed services have the same problem that prompted Westinghouse to use automatic testing: an acute shortage of highly-trained technicians.

• **For the field**—Some day, Herwald says, a soldier or airman will simply have to move test gear up to a plane, connect it to the craft's control system, and push a button. Major roadblocks right now to such a scheme are reliability of components—getting them to withstand tough field and environmental conditions—and size.

There is one final note of interest on this project. The engineers who designed the test equipment have gone about as far as they can: they have to wait now for the engineers who design the control systems to modify them for automatic testing.

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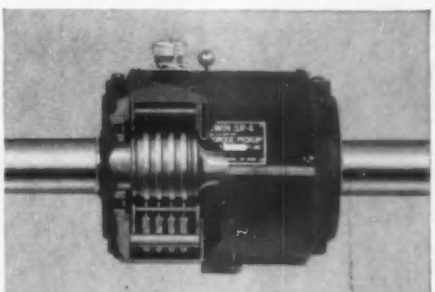
You can use Baldwin SR-4 Torquemeters to measure a few inch-ounces or thousands of foot-pounds, and with consistent accuracy to within ±¼%. They convert torsion changes directly into changes in electrical energy, measure torque independently of speed, and take no power from the drive shaft. A wide variety of instruments can be used with SR-4 Torquemeters, ranging from millivoltmeter and battery to a computing instrument reading horsepower directly.

Baldwin SR-4 Torquemeters offer unlimited application opportunities. Present uses include torque measurement of viscosity, in engine dynamometers, for pump testing, in propeller drive shafts and helicopter rotor assemblies, and hundreds of other applications in design and production testing.

Whatever *your* torque measurement problem, a B-L-H representative is ready to serve you. For more complete information on SR-4 Torquemeters, write today for your free copy of Bulletin 4308.



The Type A SR-4 Torquemeter is a self-contained unit with housing and brush assembly suspended on a shaft by ball bearings. It employs SR-4 Bonded Wire Strain Gages in a Wheatstone bridge circuit. Baldwin torquemeters have been built for shafts from ¼ in. diameter to 18 in.; for zero rpm to 35,000 rpm; and from 10 in.-oz. capacity to 4,200,000 in.-lb.

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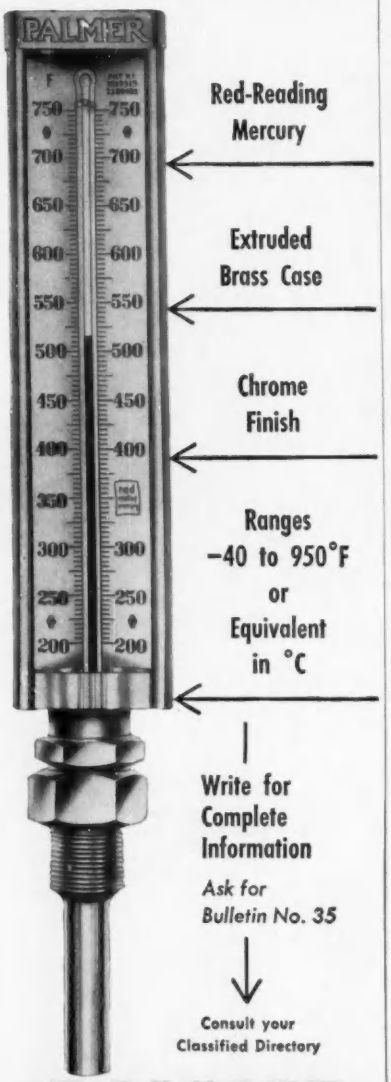
PALMER

RED-READING MERCURY THERMOMETERS



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PALMER

THERMOMETERS, INC.

Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

AROUND THE BUSINESS LOOP

IBM Shares Go to Market for First Time in 32 Years

For the past 32 years stockholders of IBM who wanted to increase their share-holdings had to be content with occasional stock-splits; no additional shares had been put up for sale since 1925. This May 21, when subscription warrants will start going out to security-holders, the corporation will write finis to the long stretch of no public offerings. Purpose of the sale is to raise about $200 million of capital funds, and only those who hold stock now will be able to buy.

Beneficent directors have another happy surprise in store for the stockholders, too, in the form of a stock-split, which will provide an additional full share for each share now held. A second-quarter cash dividend of 60 cents per share, including the shares to be issued in the split, is also in the works. Payable June 10 to holders of record on May 21, it will be equal to an increase of 20 percent on the stock outstanding before the split, which will have taken place approximately a month before.

The additional equity capital to be furnished by the stock sale is required to keep pace with the increased orders being received for IBM's electronic data-processing machines and its other products, President Thomas J. Watson Jr. explained.

P&W, NBS to Slice Inch into Tenths of a Millionth

In 1880 Pratt & Whitney Co. succeeded in achieving an exact standard of measurement within a limit of one fifty-thousandth of an inch, a measurement that gave birth to the first standard inch. Since that time the company has continued to make steady improvements on its own precision, and today many of the end gages coming off its line have accuracies of plus or minus two-millionths of an inch. But modern machining operations have more than kept pace with refinements in the inch, and these operations are demanding, in the words of Vice-President Edward J. Shages, "a degree of accuracy never before obtained".

The first stop on the road to this degree of accuracy is one-tenth of a millionth of an inch, approximately a 30,000th part of the thickness of a hair—and P&W is steaming toward it. It has assigned Albert M. Dexter Jr., gage research director, to a joint industry-government project conducted by the National Bureau of Standards and directed by Irvine C. Gardner, chief of the bureau's Optics & Metrology Div.

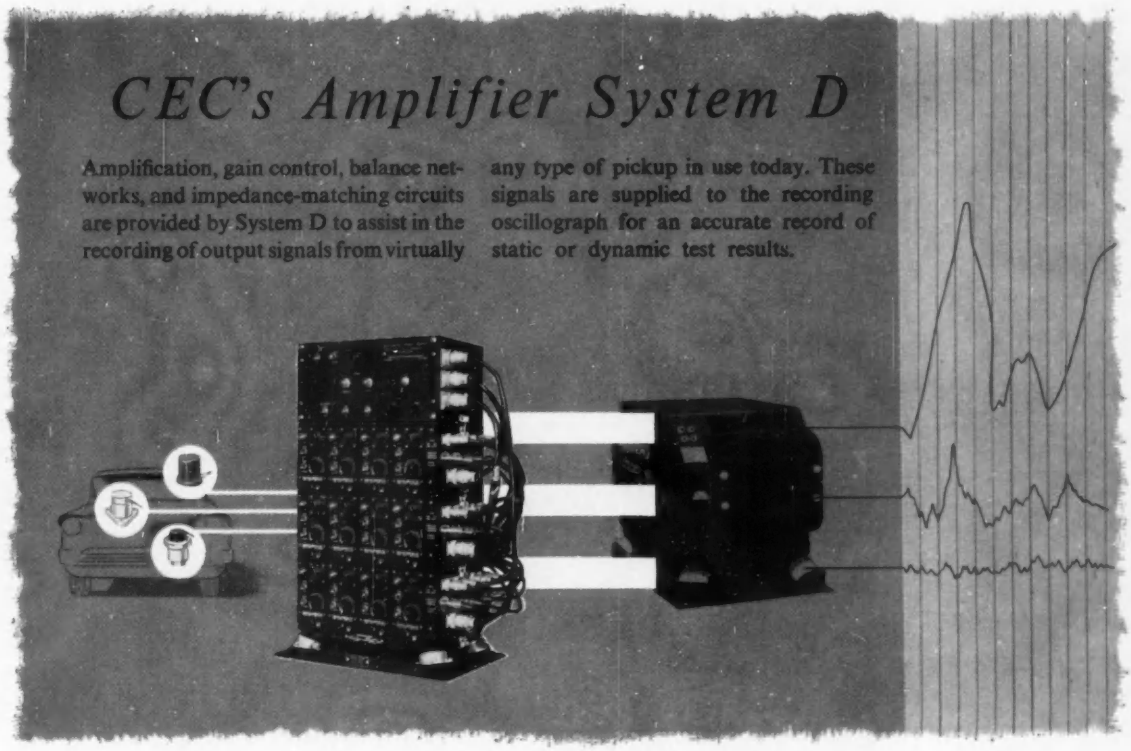
James B. Wilkie, manager of P&W's Gage Div., who explained that the wave-length of light will be used to get the new tolerance, said the project involves determining means to control temperatures to 1/100 deg F, and to control humidity, vibration, and barometric pressure, and an accurate means of measuring the "wringing interval" or "infinitesimal lengths of space" between gage blocks.

NCR Polishes Prototype of New Business-Data System

From information which it took two years to collect, The National Cash Register Co. has extruded specifications for a brand new business-data processing machine. A prototype of the NCR 304, a fully transistorized system built around an electronic computer, is now being constructed and should be completed this year. The first production model is scheduled for delivery in 1959. General Electric Co., also in on the project, is designing many of the 304's key electronic computing elements. NCR, which is building the electromechanical parts, will do the selling and servicing when the system goes on the market. Departments of both companies closest to the 304 are GE's Computer Dept. in Phoenix, Ariz., and NCR's Electronic Div. in Hawthorne, Calif., and its Engineering & Product Development Div. at Dayton, Ohio.

The development of the 304, incidentally, marks NCR's entry into the electronic computer field, an entry which takes on special significance in light of the talk of an NCR-Underwood Corp. merger. Crux of this talk is that Underwood may give up manufacture of large-scale computers and concentrate on smaller machines, particularly the Elecom 50, a $25,000 unit. There appears to be no connection between the possible merger and Underwood's change in policy, and in fact it is hard to imagine a

Eight years of proven stability and reliability


CEC's Amplifier System D
Amplification, gain control, balance networks, and impedance-matching circuits are provided by System D to assist in the recording of output signals from virtually any type of pickup in use today. These signals are supplied to the recording oscillograph for an accurate record of static or dynamic test results.

Amplification for multichannel recording

Companies who purchased Consolidated's System D when it was first introduced eight years ago report that these same amplifier systems are still giving consistently stable, high-precision performance in steady use. Maintenance costs have been negligible.

Rugged, lightweight construction and ability to perform over a wide range of temperatures make Amplifier System D ideal for laboratory, field, and flight-test applications. A typical System D consists of any combination of linear/integrating amplifiers and/or carrier amplifiers up to a maximum of 12 channels, a combination oscillator/power supply, and a shockmount base. Contact your nearby CEC field office, or write for Bulletin CEC 1403-X2.

Consolidated Electrodynamics

CEC *300 North Sierra Madre Villa, Pasadena, California*

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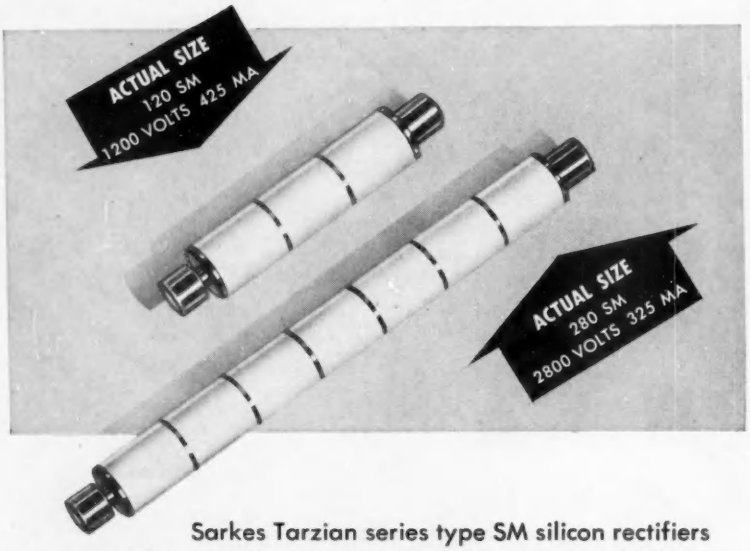
Your Demands Created

HIGH VOLTAGE
SILICON POWER RECTIFIERS



Sarkes Tarzian series type SM silicon rectifiers provide the practical, low cost solution to the high voltage silicon rectifier problem. Stable characteristics inherent in low voltage junctions are carried over to this series. If your application calls for high temperature and high voltage, send for complete information.

ELECTRICAL RATINGS

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes								Jetec No.
			Max. D.C. Load		Max. RMS		Max. Recurrent Peak		Surge 4MS Max.		
			100°C	150°C	100°C	150°C	100°C	150°C	100°C	150°C	
80SM	800	560	.450	.225	1.12	.560	4.5	2.25	27.0	13.5	1N1108
120SM	1200	840	.425	.212	1.06	.530	4.25	2.12	25.5	12.7	1N1109
160SM	1600	1120	.40	.200	1.00	.500	4.00	2.00	24.0	12.0	1N1110
200SM	2000	1400	.375	187	.940	.470	3.75	1.87	22.5	11.2	1N1111
240SM	2400	1680	.35	175	.875	.437	3.50	1.75	21.0	10.5	1N1112
280SM	2800	1960	.325	162	.812	.405	3.25	1.62	19.5	9.7	1N1113

DIMENSIONS

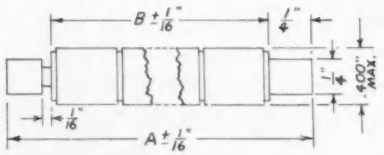


Figure 1

Figure 1		JETEC NO.
A	B	
1-15/32"	31/32"	1N1108
1-15/16"	1-7/16"	1N1109
2-13/32"	1-29/32"	1N1110
2-7/8"	2-3/8"	1N1111
3-11/32"	2-27/32"	1N1112
3-13/16"	3-5/16"	1N1113

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RECTIFIER DIVISION

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EXPORT: AD AURIEMA, INC., NEW YORK CITY

company like Underwood turning over large-computer manufacturing facilities to a company like NCR, which is just getting started in the business.

Underwood's decision (if it can be called that at this time) stems from strictly intracompany developments. It is said to be the only computer-maker to have slipped financially in a period of hearty traffic in complex office machines. For specifics, see the article below on 1956 statements by control manufacturers. Underwood also cites as reasons for the move: the very expensive R&D work associated with the big computers, the relatively small market for them, and the inflexible long-range capital requirements which they necessitate.

Most Control Firms Submit Favorable 1956 Statements

In the last weeks many control firms have prepared and submitted year-end statements for the year 1956. Among them:

American Bosch Arma Corp.: Sales up 66 percent to $122,237,735; earnings up from $3,383,568 to $4,626,357; military backlogs of the Arma and Chicago Divs. up from $175 million to $300 million, due principally to work on the defensive system for the B-52 jet bomber, and to development and production of an ICBM guidance system.

American Electronics, Inc.: Net sales up 75 percent to $10,379,641; net income up 42 percent to $376,128.

Clevite Corp.: Sales up from $73,088,935 to $75,111,784; net income down from $4,854,753 to $3,971,593.

E. I. du Pont de Nemours & Co., Inc.: Sales down 1 percent from a record 1955 to $1,888,000,000; net earnings down 13 percent; average operating investment up 7 percent.

General Precision Equipment Corp.: Sales up 15 percent to $153,261,864; backlog up from $127,192,000 to $167,660,000; net profit down from $2,530,758 to $2,394,729; net capital loss about $3 million. Among adverse factors blamed for the lower '56 figures were a protracted strike at the International Projector Corp. of Bloomfield, N. J. (now Simplex Equipment Corp.), liquidation of Ampro Corp., and losses on a fixed-price military contract.

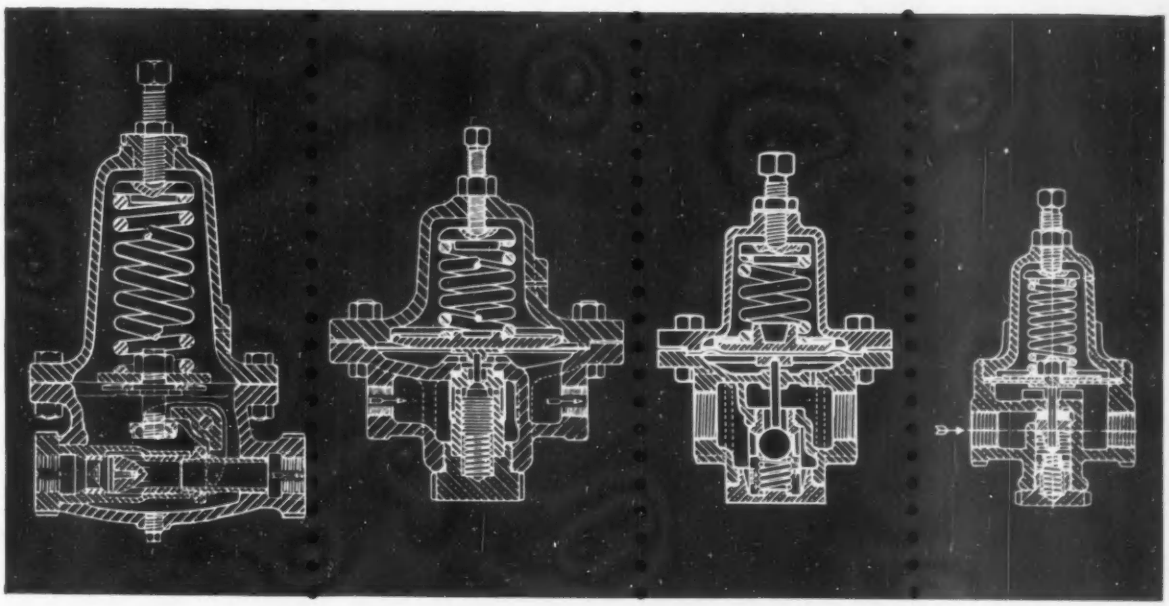
General Transistor Corp.: Net income $183,784, compared to a loss of $5,720 in 1955, the firm's first year.

G. M. Giannini & Co., Inc.: Sales

What's your pressure problem?

CASH STANDARD

has the answer... *or will find one!*



HERE ARE FOUR TYPES FOR MANY APPLICATIONS

TYPE 1000 — A streamlined, high capacity valve for close pressure regulation—accurate even under toughest working conditions. Closes against the flow, eliminating conditions that cause chatter. Sizes: ¼" to 2", screwed ends. Bulletin 962.

TYPE D — A general purpose regulator with exceptional regulation characteristics. Now improved to permit easier servicing but basically the same dependable valve offered for over 35 years. Sizes: ¼" to 2". Bulletin 950.

TYPE 1260 — A high capacity pressure regulator, small and well proportioned. Available with spherical, self-cleaning inner valve. Suitable for air, water, steam, oil and most fluids and gases. Sizes: ½", ¾", 1", screwed ends. Bulletin S-700.

TYPE 3381 — A small, compact, all-bronze pressure regulator, very accurate and dependable. Available with pressure gauge mounted in one of the two outlet connections. For small lines. Sizes: ¼" and ⅜", screwed ends. Bulletin 948.

There's a Cash Standard regulator for every pressure control problem!

For an individual solution to your control problem, contact the Cash Standard control specialist in your area, or write Dept. F.

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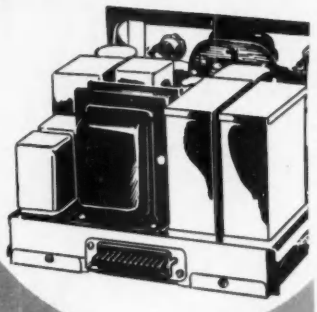
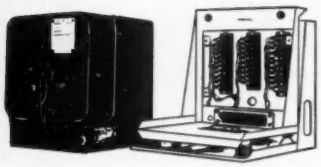
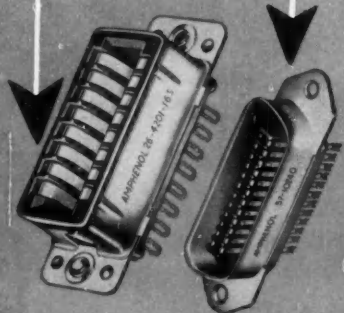
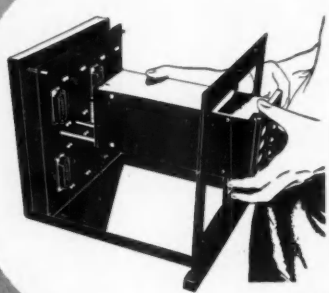
Pressure, Hydraulic, Temperature, Process and Combustion Controls

PLUG IN with BLUE *Ribbon* CONNECTORS









AMPHENOL's Blue Ribbon connectors have gold-plated "ribbon"-like contacts and diallyl phthalate dielectrics. They are available with guide pin or contact barrier polarization and as inserts with mounting plates or in keyed shells. Up to 32 contacts are provided in standard size connectors and as many as 50 in new Micro-Ribbon versions.

In hundreds of rack & panel applications, Blue Ribbon connectors are providing reliable, quick connection for plug-in sub-assemblies. Performance proved, Blue Ribbons can do an equally efficient job for you.

AMPHENOL ELECTRONICS CORPORATION
chicago 50, illinois
AMPHENOL CANADA LTD., *toronto 9*

WHAT'S NEW

up nearly 50 percent to $9,510,091; backlog more than doubled to $6,230,000; net income $339,521.

Hazeltine Corp.: Earnings up from $1,604,824 to $1,873,162.

International Resistance Co.: Net sales up from $15,684,722 to $16,787,913; profits slightly down from $533,296 to $523,416.

Link-Belt Co.: Sales up 27 percent to $163,921,863; net earnings up 46 percent to $11,072,134.

Minneapolis-Honeywell Regulator Co.: Sales up 18 percent to $287,944,490; net profits up from $19,278,648 to $22,463,657; capital expenditures up from $13,051,700 to $15,396,100; working capital up from $86,086,490 to $111,385,862; aeronautical and ordnance backlogs largest in history.

National Research Corp.: Net income of $849,393, compared with a net loss in 1955 of $337,381; net capital gain of $646,500. These figures indicate profits in excess of earlier estimates.

Norden-Ketay Corp.: Sales up 68 percent to $22,752,993; net loss up from $236,203 to $505,280; backlog up from $21 to $24 million.

Robertshaw-Fulton Controls Co.: Sales up 13 percent to $72,640,000; net income up 15 percent to $4,220,000.

Stewart-Warner Corp.: Sales up 7 percent to $121,264,742; net income up 8 percent to $6,632,399 (the highest in 27 years); inventories up 3 percent.

Texas Instruments, Inc.: Sales up 59 percent to $45,699,358 (military: up 45 percent to $12,850,247, or 28 percent of the total); net earnings up to $2,349,103.

Tung-Sol Electric, Inc.: Net sales up 5.3 percent to $53,838,822; net earnings down from $3,239,393 to $2,909,397.

Underwood Corp. (for the first nine months of 1956): Net sales $62,306,088, resulting in a deficit of $5,831,005. This deficit is said to have been stopped from getting any larger by a fast decision to abandon R&D work in large-scale computers (see story above).

U. S. Industries, Inc.: Sales up 30 percent to $105,431,774; net income up 9 percent to $4,413,816.

Walworth Co.: Net sales up from $51,609,026 to $84,308,978; net income up from $2,354,141 to $4,476,051; net capital $22,965,187.

Westinghouse Electric Corp.: Net sales up 6 percent to $1,525,375,000;

(Continued on page 182)

No matter what factors govern your choice of precision components...

THE ANSWER IS HERE

The Fairchild line of precision components includes *forty-two standard types* of precision potentiometers, pressure transducers and accelerometers. Please note that this does not include any of the countless specials or design variations on basic units that we have made for various customers . . . or could make for you.

The 42 standard types embody *seventeen basic product categories* including wire wound or metal film, single- or multi-turn, linear and non-linear in both phenolic and metal cases; and high temperature types. Pressure transducers, accelerometers, trimmer potentiometers and linear motion potentiometers are also available.

In all these, Fairchild's continuing and extensive research now provides you with the optimum designs for size and functional conformity to best meet your individual needs. *Whatever* your potentiometer or transducer problem is, let Fairchild help you. Write for our new condensed catalog. Fairchild Controls Corporation, Components Division, Dept. 140-82C.

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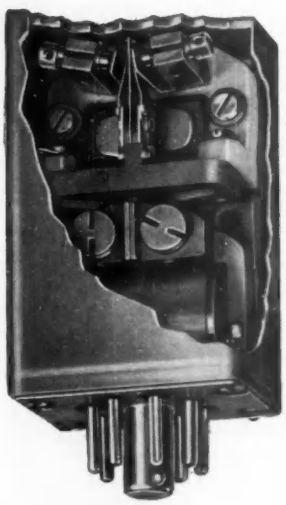
FAIRCHILD
PRECISION POTENTIOMETERS and COMPONENTS

ALLIED'S NEW

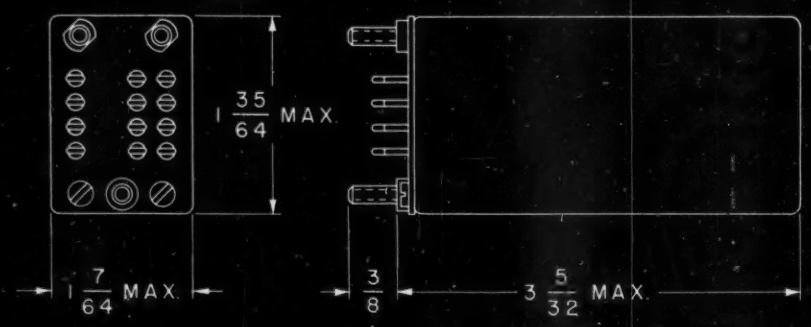
Allied Types
Trls 163-169

Actual Sizes

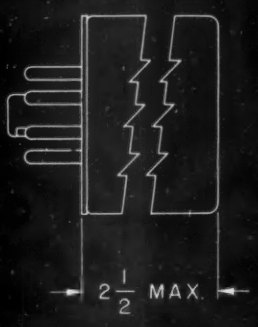
This new polarized relay, designed and manufactured by Siemens & Halske Company of Germany, is now available from Allied Control, and in the near future will be produced by Allied with the technical assistance of Siemens & Halske.



Allied Types
Trls 193-199



Trls 163-169 with SOLDER TERMINALS



Trls 193-199
with OCTAL BASE

Sealed POLARIZED RELAYS

Specifications for Allied's Types TRIs 163-169 and TRIs 193-199

Type Number		TRIs 163 TRIs 193	TRIs 164 TRIs 194	TRIs 165 TRIs 195	TRIs 166 TRIs 196	TRIs 167 TRIs 197	TRIs 168 TRIs 198	TRIs 169 TRIs 199
Description	Positions	2		3	2	2	3	2
	Operation	Magnetic Latch						
		High Contact Pressure	High Sensitivity	Null Center	Magnetic Latch	Spring Biased	Null Center	Spring Biased
Contact Arrangement		SPDT		SPDT	DPDT	SPDT	DPDT	DPDT
"Operate" Excitation (Std.)	Amp. Turns	7	2	2.2	5.5	5	4	15
"Operate" Power TRIs 163-169	μ Watts	500	40	50	300	250	160	2250
"Operate" Power TRIs 193-199	μ Watts	610	49	61	375	300	195	2750
"Working" Excitation	Amp. Turns	15	4	6	10	10	10	25
"Release" Excitation	Amp. Turns			2.2		2.4	4	5
Max. Rate of Operation	Oper./Sec.	200	200	200	200	100	200	100

Shock and Vibration: The degree of shock and vibration resistance is related to the type of operation, the adjustment, the coil input power and the application. Contact Allied Control for ratings for your specific application.

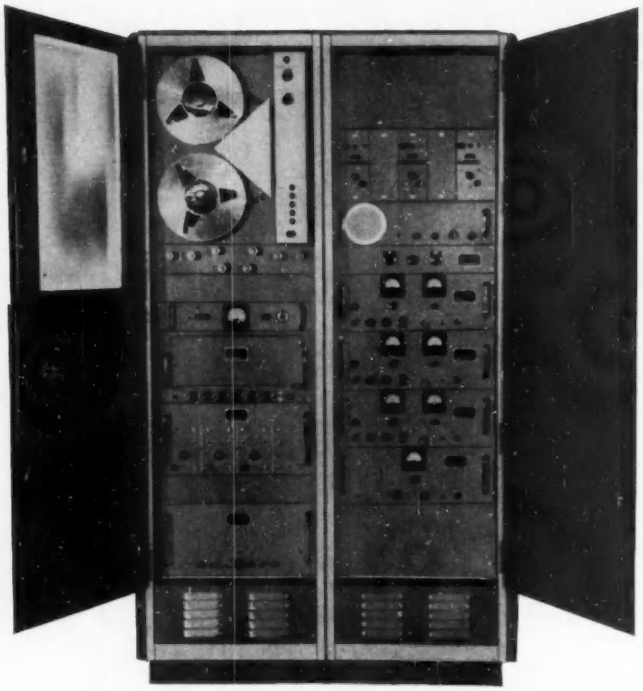
Contacts:	Silver, General Purpose 2 amp., 28v d-c resistive load
	Platinum Alloy A. Low-Level Applications up to .5 amp.
	Platinum Alloy B. Heavy Duty Applications above .5 amp.
	Max. Continuous Current 5 amps.

Dielectric Test Voltage	Coil to Frame	500v rms.
	Contact to Contact	350v rms.
	Contact to Frame	500v rms.
	Winding to Winding	150-500v rms.
Standard Coils	Resistances from 1.1 to 18,000 ohms	
	Max. number of windings	3
	Max. Continuous Loading	1 watt
Temperature	Max. Ambient	85°C

ALLIED CONTROL

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N.Y.

NEW UNIVERSAL SYSTEMS



meet 90% of magnetic tape data recording needs

You get all the precision and accuracy of a custom design *and* the off-the-shelf availability and dollar savings of a "package" design in Davies new Universal Tape Systems.

Every component has been designed to provide maximum flexibility consistent with overall system accuracy. Interchangeable electronics match the system to *your individual requirements* . . . now and for years to come. Specify a Universal System that satisfies your *immediate* requirements . . . adding tracks of data capacity as requirements grow.

Any one of the maximum of fifteen tracks provided can carry data recorded by any one of the three major techniques. Interchangeable Direct, FM, and PWM electronics assure you a *vital* data recording system . . . able to handle each new job as it arises. Standard options are also available to meet the special needs of telemetering and multiplexed data.

Among the features of a Davies Universal Tape System never before available in "package" equipment are six tape speeds at the flip of a switch . . . automatic switching discriminators that match tape speed at the transport . . . precise phase coincidence of data among all tracks . . . and facilities for electronic flutter-and-wow compensation. Every item has been proved through years of service in jets, missiles, and on the ground.

Here's a brief rundown of the options available to you when specifying a Davies Universal Tape System that will grow with your recording requirements:

Transport: Standard transport offers up to six speeds, selectable at the flip of a switch. Precision 10½" or 14" reels available for 1" or 1½" tape. Three-speed transport optional for PWM systems.

Heads: In-line multitrack heads permit up to 15 tracks on 1½" tape, assure precise time and phase coincidence of data among all tracks. Separate record and playback heads provided. Interleaved head stacks permitting up to 30 tracks on 1½" tape, optional for telemetering, other applications not requiring data coincidence.

Direct Recording electronics record and playback data from 100 to 100,000 cps. Ideal for high frequency data, also for recording complex wave forms made up of many frequency multiplexed signal channels. Bandpass type discriminators provided for recovering multiplexed data.

FM electronics frequency modulate a stable carrier with the data, to provide extremely accurate data reproduction, independent of tape variations.

Pulse Width Modulation (PWM) electronics permit up to 90 channels of quasi-static data on each tape track. All PWM electronics are compatible with standard keyers and decoding equipment.

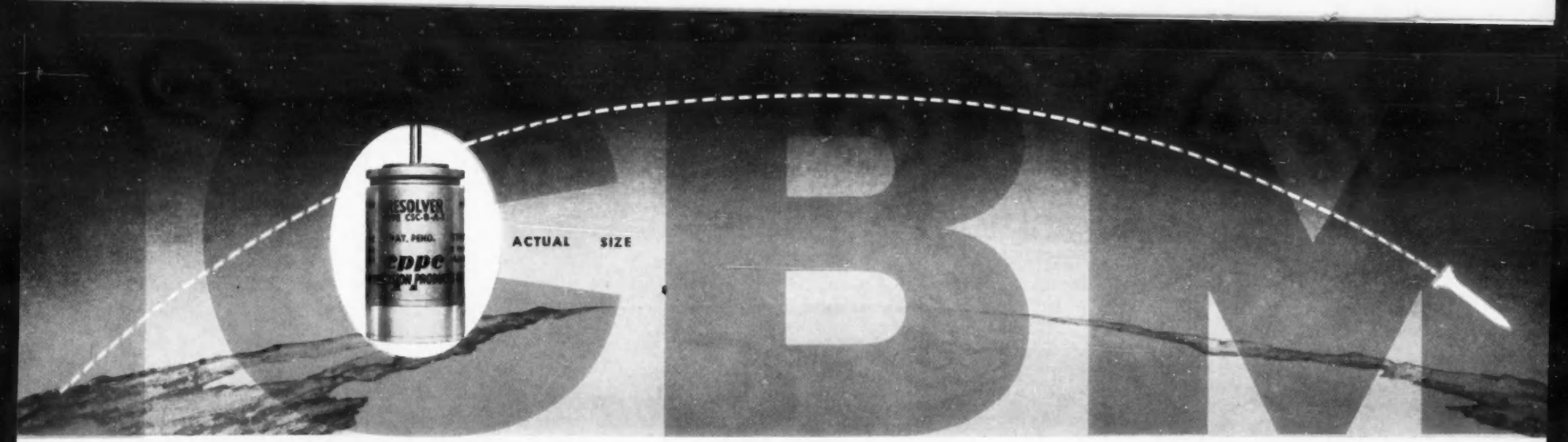
Flutter-And-Wow Compensation electronically eliminates the effects of tape speed variation. Included as standard equipment whenever discriminators are used for data recovery, they can be accommodated by every Universal Tape System. Compensation permits FM channels of a Universal Tape System to preserve a high signal-to-noise ratio—better than 50 db at 30 ips, for example.

COMPLETE INFORMATION *on Davies new Universal Tape Systems, and how they can satisfy your magnetic tape data recording needs is provided in Bulletin 2701. Write for your copy to Minneapolis-Honeywell Regulator Co., Davies Laboratories Division, 10721 Hanna Street, Beltsville, Maryland. Or call Webster 5-2700.*

MINNEAPOLIS **Honeywell**

DAVIES LABORATORIES DIV.

Obtain your Scotch Brand recording tape for all instrumentation recording needs at your nearest Honeywell Industrial Sales Office.



When Minutes (of error) Mean Miles "off target"

specify Clifton Precision Size 8 Synchros

for

HIGHEST ACCURACY

SYNCHRO FUNCTION	CPPC TYPE	ROTOR AS PRIMARY						STATOR AS PRIMARY						D.C. RESISTANCE		IMPEDANCE			Max. Null Voltage (MV)	Max. Error (Min.)
		Input Voltage (400 ~)	Input Current (Amps.)	Input Power (Watts)	Output Voltage (Volts)	Sensitivity (MV/deg.)	Phase Shift (deg. lead)	Input Voltage (400 ~)	Input Current (Amps.)	Input Power (Watts)	Output Voltage (Volts)	Sensitivity (MV/deg.)	Phase Shift (deg. lead)	Rotor (Ohms)	Stator (Ohms)	Zro (Ohms)	Zso (Ohms)	Zrs (Ohms)		
Torque Transmitter	CGC-8-A-7	26	.100	.5	11.8	206	8°	–	–	–	–	–	–	37	12	54+j260	12+j45	80+j20	30	7
Control Transformer	CTC-8-A-1	–	–	–	–	–	–	11.8	.090	.23	23.5	410	8.5°	143	25	220+j740	28+j110	246+j60	30	7
Control Transformer	CTC-8-A-4	–	–	–	–	–	–	11.8	.029	.08	22.5	390	8°	389	64	560+j1860	90+j340	640+j190	30	7
Torque Receiver	CRC-8-A-1	26	.100	.5	11.8	206	8°	–	–	–	–	–	–	37	12	54+j260	12+j45	80+j20	30	30
Electrical Resolver	CSC-8-A-1	26	.039	.43	10.6	185	20°	11.8	.084	.27	23.2	400	11°	230	27	280+j600	38+j136	70+j136	30	7
Electrical Resolver	CSC-8-A-4	26	.039	.43	26	454	20°	26	.038	.30	27.5	480	13°	230	150	280+j600	200+j660	70+j140	30	7
Control Differential	CDC-8-A-1	–	–	–	–	–	–	11.8	.085	.21	11.8	206	9°	36	25	38+j122	27+j120	48+j14	30	7
Vector Resolver	CVC-8-A-1	26	.057	.34	11.8	206	10.2°	–	–	–	–	–	–	78	27	103+j440	8+j30		30	7

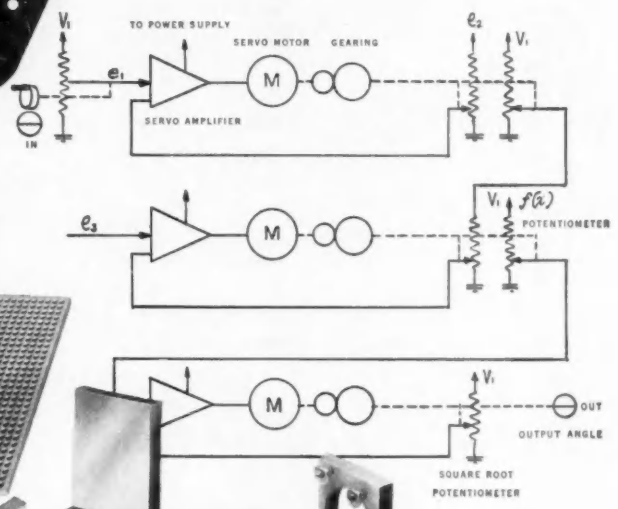
LOOK TO CPPC FOR SYNCHRO PROGRESS

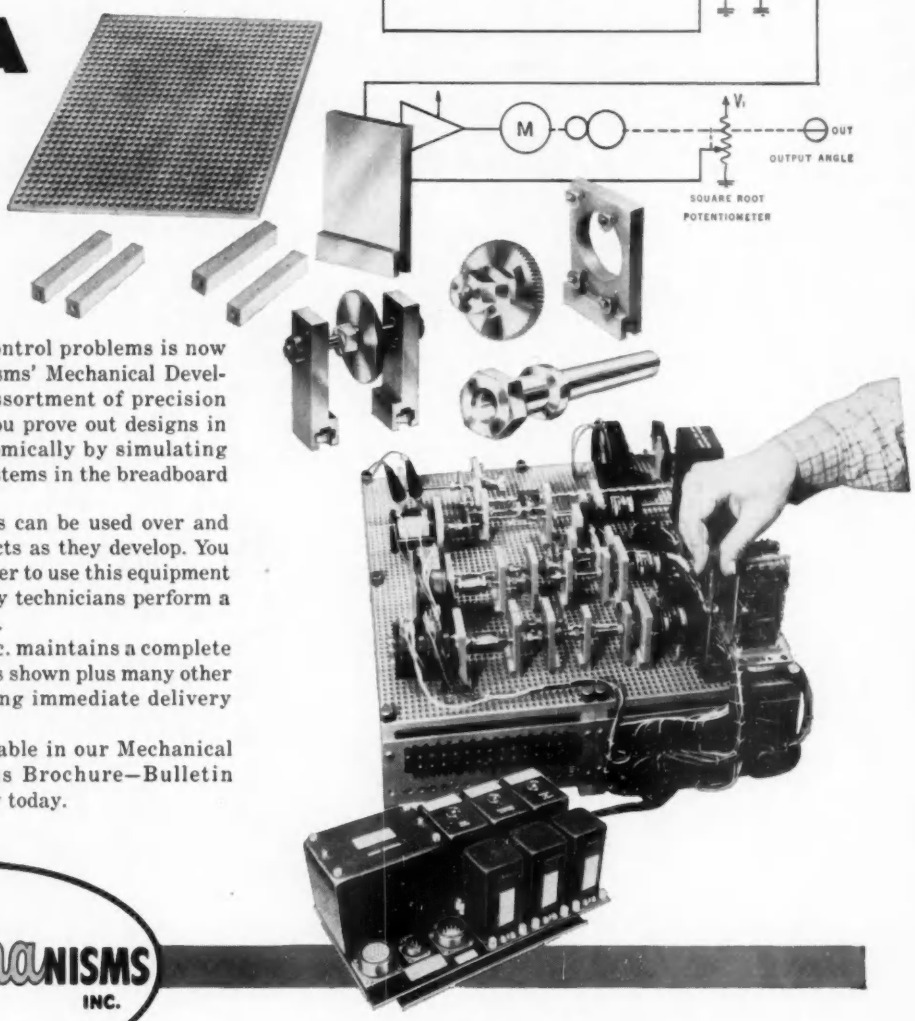
CLIFTON PRECISION PRODUCTS CO. INC. cppc **Clifton Heights, Pa.**

when you want ANSWERS...

$$\theta_{OUT} = \sqrt{\frac{f(e_2 e_3)}{\theta_{IN}}}$$

you can get them quickly with MDA





Getting the answers to control problems is now easier with Servomechanisms' Mechanical Development Apparatus—an assortment of precision mechanical components. You prove out designs in the lab quickly and economically by simulating instrument and control systems in the breadboard phase.

And, MDA components can be used over and over again on other projects as they develop. You do not need to be an engineer to use this equipment—in many cases laboratory technicians perform a major portion of the work.

Servomechanisms, Inc. maintains a complete stock of all the components shown plus many other companion parts—insuring immediate delivery from a single source.

Full details are available in our Mechanical Development Apparatus Brochure—Bulletin MDA200. Write for a copy today.

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FREQUENCY STANDARDS

TYPE 50

AVIONIC
FREQUENCIES
PRECISION FORK

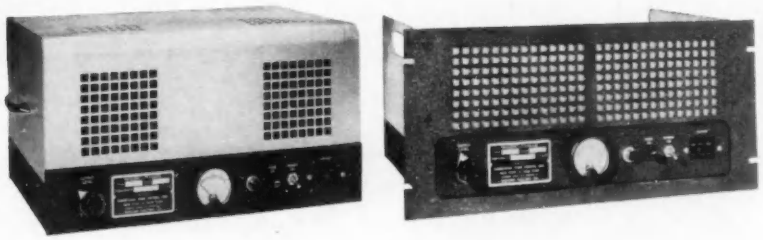
FREQUENCIES
240–400–500–1,000 cy.

ACCURACIES
Type 50 ±.02% (—65° to 85°C)
Type R50 ±.002% (15° to 35°C)

Requires double triode and 5 pigtail components

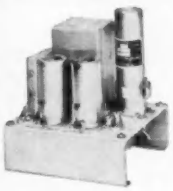
Size, 1" diameter x 3¾" high
Weight, 3.5 ounces

POWER
75 Watt
FREQUENCY STANDARD
TYPE 211C



FREQUENCIES: .....50 to 1,000 cycles
ACCURACY: ..±.002% (+15° to +35°C)
OUTPUT: .....115V, 75 Watts
INPUT: .....110V, 50 to 75 cycles
SIZE: with cover....10"x17"x9" high
PANEL model,..10"x19"x8¾" high
WEIGHT: .....25 pounds

INDUSTRIAL



FREQUENCY STANDARD
TYPE 50L

FREQUENCIES
50–60–75 or 100 cy.

ACCURACIES
TYPE 50L
±.02% (—65° to 85°C)
TYPE R50L
±.002% (15° to 35°C)

INPUT: 150 to 300V, B (6 V at .6 amps.)
OUTPUT: .....2V into 200,000 ohms.
SIZE: ..3¾"x4½"x5½" high. Wgt., 2 lbs.

This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government, (armed forces) where maximum accuracy and durability are required.

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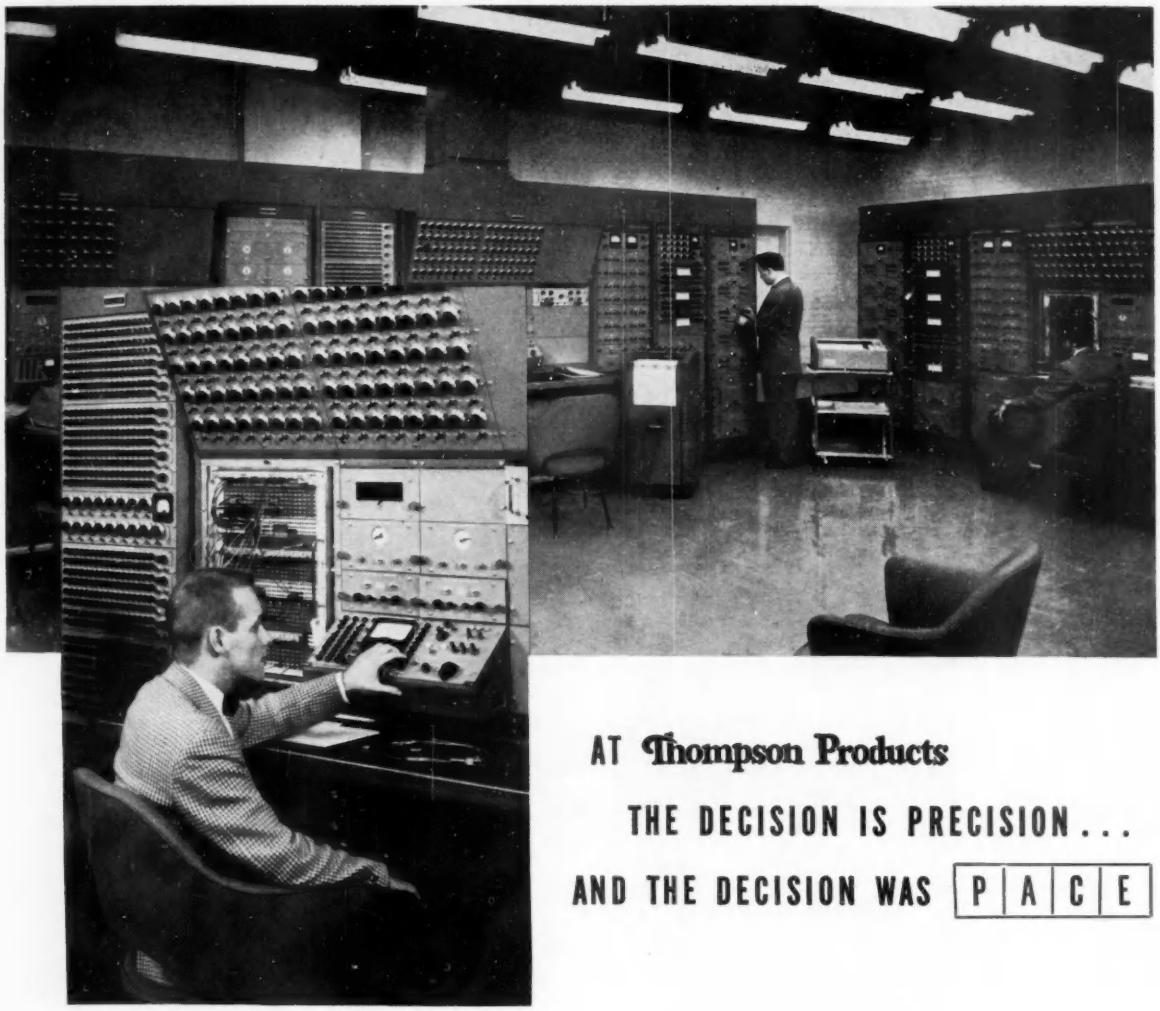

AT Thompson Products

THE DECISION IS PRECISION . . .

AND THE DECISION WAS P A C E

Another example of major industry breaking through the problem barrier:

The New Device Research Department, a privately owned laboratory of Thompson Products, Inc., recently placed in operation one of the country's largest analog computing systems devoted to the solution of aeronautical control and nuclear control problems.

This PACE Computing System developed by Electronic Associates, Inc. will also be applied to industrial control problems.

The combination of non-linear and linear computing equipment enables wide-range simulation of electrical, mechanical, and pneumatic systems to be accomplished.

In research and simulation as vital as those at Thompson Products, the major decision is precision. And the high standard of accuracy of EAI Equipment sets the PACE for precision in the industry.

For a demonstration or for rental of time, contact our Computation Centers. There's a Center serving Eastern Industry in Princeton, N. J.—one serving Western Industry in Los Angeles, Calif. For equipment information, write Electronic Associates, Inc., Long Branch, N. J., Dept. CE-5.

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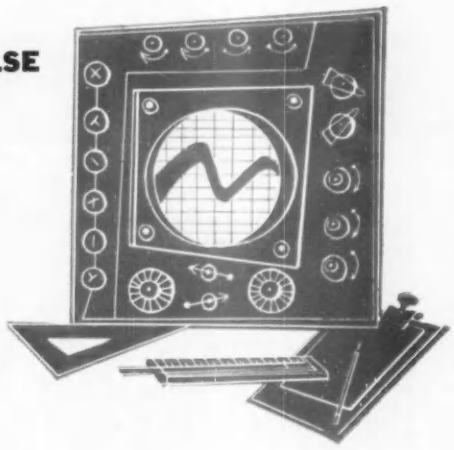
EAI SETS THE P PRECISION A ANALOG C COMPUTING E EQUIPMENT ®

LONG BRANCH • NEW JERSEY



Control Engineers Revitalize DC Equipment Business

For the past ten years, manufacturers of dc rotating equipment have happily watched a new market mushrooming for their products. The market: applications in control. The steadily growing use of sophisticated controls, built around dc equipment, has almost quadrupled sales of such gear since the war.

Control uses swell dc sales

Just before the 1929 crash, the dc-equipment business hit bottom. Then, the main application was in a constant-speed drive in areas that clung to dc distribution systems. But as the dc lines disappeared, dc equipment vanished, too. The development of rotating regulators in the mid-30's stopped the slide, and World War II equipment needs accelerated the adoption of dc gear in control applications.

Why dc?

For control engineers, the major advantages of dc equipment are flexibility and versatility in controlling speeds. With a dc generator feeding a dc motor, for example, it's possible to get almost any speed or torque desired—by varying the field of the generator or the motor, or both. To get the same kind of control with ac equipment, an engineer would be forced to use some technique like a high "slip" motor or a wound-rotor motor. Both of these methods are wasteful of power (generated heat dissipates externally) and add a cooling problem to the equipment design.

Perhaps the most spectacular growth in dc equipment has been in the over-1-hp sizes of integral-hp motors and generators. Because such equipment combines a good source of torque and speed-control with an easy means of quick stopping or reversing, it is being used in such widely-diversified applications as machine-tool control—lathes, boring mills, sliders, milling machines, etc.; materials-handling equipment; graphic-arts equipment, such as printing presses; cement-industry equipment, including kiln drives, feeder drives and cooler drives; textile machinery; paper-industry drives; and packaging machinery.

Figures tell the story

According to industry sources, control engineers have boosted sales from just over $16 million in 1949 to $44 million in 1956—and that includes only dc motors and generators from 1 to 200 hp and excludes m-g sets. Almost every company in the field has sales figures to substantiate this gain. Reliance Electric & Engineering Co. reports dc sales

MICRO SWITCH . . . FIRST IN PRECISION SWITCHING

Consider the many features of this small limit switch

Compact—Completely Sealed—Double-Pole, Two Circuit—Operating Force Only 3 Pounds Maximum

This LS series switch is extremely small for a limit switch of such ruggedness. It is a double-pole, two-circuit switch but can be used single-pole double-throw.

The housing is of heavy cast aluminum. Four mounting holes in the flanged portions of the casting—not through the switch cavity—assure vibration-proof installation. The cover screws and lock washers are held captive in the cover when cover is removed. They cannot drop out. Cover seal is cemented to the cover—it is always there.

Four .192 in. diameter mounting holes extend through the enclosure. They are tapped from the back to a depth of 9/16 of an inch with ¼-20 nc thread. They accept No. 10 screws. Switch can be mounted from either front or back side.

The switch is fitted with No. 8 terminal screws which easily accommodate No. 14 stranded wire.

Full details will be found in Catalog 83.

CHARACTERISTICS

Operating force—3 lbs. max. Pretravel—20° max. Full overtravel force—6 lbs. max. Differential travel—12° max. Release force—½ lb. min. Overtravel—30° min.

Rated: 10 amps. 120, 240, 480 vac; ½ H. P. 120 vac; 1 H. P. 240 vac; .8 amp. 115 vdc; .4 amp. 230 vdc; .1 amp. 550 vdc. Pilot duty rating 600 vac max.

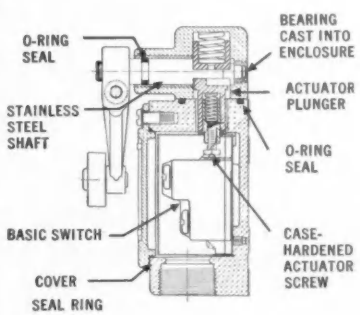
Field Adjustable Through 360°

The strong, rugged actuator arm, fitted with either steel or non-sparking roller can be adjusted in the field through 360°. It can be securely locked in any position. It is designed to operate in either direction or in one direction only—clockwise or counter-clockwise. Simply remove the actuator head and rotate the notched plunger 90°. Head may be rotated to provide actuation from any of four quadrants.

Any MICRO SWITCH Field Engineer can assist you in designing the LS into your product—or call an Authorized Distributor as to how you can modernize present equipment.

The LS is Completely Sealed

Note the illustration at the right. It shows the features of the switch and the thorough sealing provided by the use of O-ring seals on the actuator shaft and between the actuator head and the housing. A synthetic rubber seal on the cover never becomes loose—it is sealed to the cover. These seals provide maximum protection against dust, lint, oil and other liquids.



MICRO SWITCH
A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY
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have more than doubled since 1949. Louis Allis points to a 300-percent gain in dc motor sales between 1947 and 1956. Allis-Chalmers says its dc motor sales for 1956 were 382 percent over 1947. GE and Westinghouse sales curves show a comparable upward swing.

These kinds of gains have made equipment manufacturers acutely conscious of what control engineers want. The requirements: 1) a high torque-inertia ratio; 2) accelerating capacity; and 3) stability. And the industry is trying hard to deliver. Within the last 18 months, NEMA standards for dc equipment have been changed to mirror the new emphasis on control applications. Reliance and GE have brought out new lines of dc motors within the past year, and Westinghouse just announced a new line on April 25th (see page 128 for details). Allis-Chalmers is modifying its line to meet the new NEMA standards.

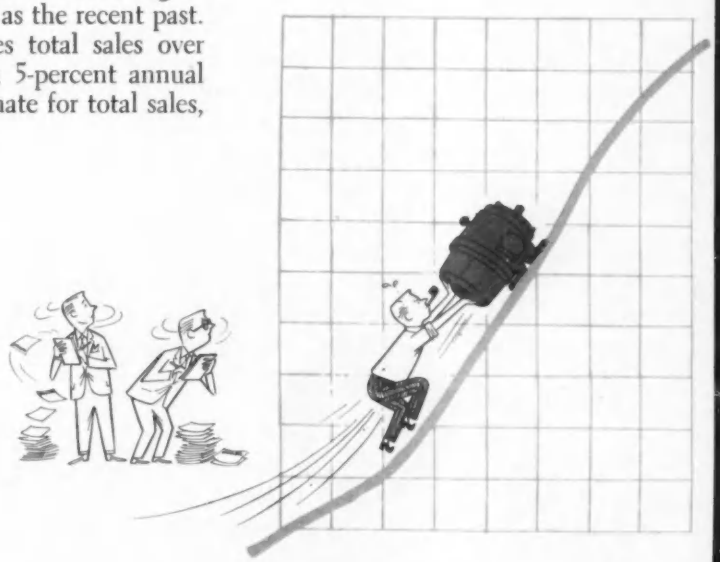
Today in the newly announced dc rotating equipment lines you see these "signs of the times":

Signs of the times

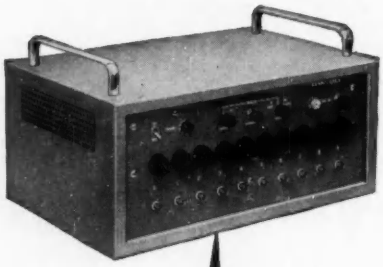
- ▶ Decreased response time, brought about by sharply reducing moment of inertia. Smaller diameters and longer armatures fit applications with reversing or high-acceleration requirements.
- ▶ Improved commutation ability to allow high currents for sudden stopping and quick reversing.
- ▶ Improved stability by such design techniques as extra-strong shunt fields with large air gaps.
- ▶ Improved insulation to allow continuous operation for sustained periods of time.

One of the major changes that NEMA made was to associate closely each generator size with a motor size. Previously, dc-generator capacities were standardized in arbitrarily chosen steps. Now each generator rating is matched to a motor rating. Another change, raising dc-motor ratings from 230 to 240 volts, recognized that most motor applications use a packaged drive where voltage drop between generator and motor is normally very small.

The future for integral-size dc motors and generators looks every bit as good as the recent past. One market-research man sees total sales over $100 million by 1958, with a 5-percent annual gain thereafter—that's an estimate for total sales, including m-g sets.



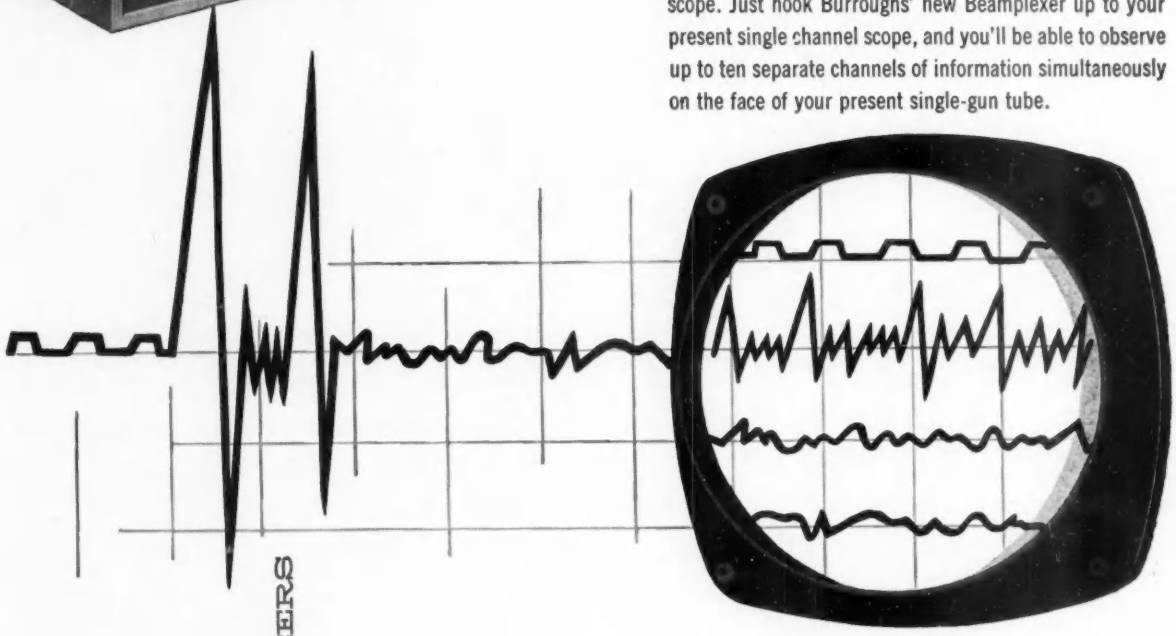
make your scope multi-channel



NEW BURROUGHS BEAMPLEXER

displays up to 10 separate signals on a single-channel scope simultaneously

Now you can have the advantages of multi-channel oscillography at a fraction of the cost of a multi-channel oscilloscope. Just hook Burroughs' new Beamplexer up to your present single channel scope, and you'll be able to observe up to ten separate channels of information simultaneously on the face of your present single-gun tube.



TOOLS FOR ENGINEERS

The Beamplexer is actually a fast electronic switch. Its heart is the Burroughs Beam Switching Tube which acts as a gate, picking the ten parallel input signals off in sequence, at adjustable speeds ranging from push button to 100 kc, and putting them out on one line. Each signal can be located on the scope as desired, and even superimposed on one another through individual positioning pedestal controls for each channel. Other controls include separate amplification for each channel.

Power consumption is 120 volts a-c, 60 cps, single phase, 0.73 amps, with the entire unit self-contained for cabinet or standard relay rack mounting.

Full details on how the Beamplexer can make your scope more useful . . . make your time more efficient . . . are given in Technical Bulletin 346 available for the asking. Write for your copy.

Burroughs

BURROUGHS CORP. • ELECTRONIC INSTRUMENTS DIVISION
Department A • 1209 Vine Street • Philadelphia 7, Penna.

Control ENGINEERING
MAY 1957

Reduce Meeting Redundancy

Attendance at technical society meetings is definitely worthwhile. An updating on who's doing what, informal discussions of mutual engineering problems, and general refreshers on new techniques are benefits which all gain by attending. But you can't possibly attend them all. Is it tough to decide which ones on measurement and control would be most valuable to you? Does your management budget the frequency and geographical locations of meetings to which it will send you? Do you struggle to pick out of the welter of many meetings the few bits of information which relate directly to design and application problems assigned to you?

If you answer "Yes" to any of these questions, you should be glad to know that a North American Control Council was formed on March 21 by authorized representatives of the American Society of Mechanical Engineers, American Institute of Electrical Engineers, Institute of Radio Engineers, Instrument Society of America, and American Institute of Chemical Engineers. Its immediate objectives:

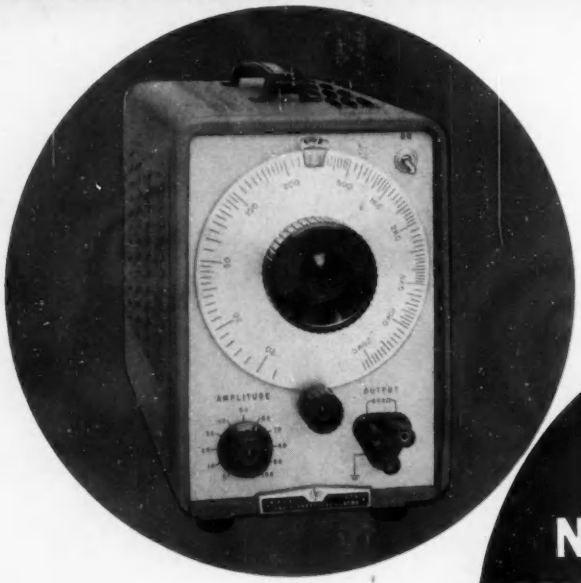
1) to represent the engineering and scientific societies of this country in the proposed International Federation of Control (see Jan. '57 editorial);

2) to coordinate the technical activities, in control systems engineering, of NACC-affiliated societies (see March '55 editorial).

Both objectives should mean less overlap in subject matter and scheduling. They should mean that each meeting will have a more specific scope and that you can therefore call your shots by attending those meetings which bear most closely on your work. Watch *What's New* in the next issue for concrete results of the first efforts at coordination.

As secretary of the NACC, the editor of this magazine invites your comments and preferences on coordination.

THE EDITORS



Now!

New low cost oscillator covers entire audio band in one sweep of the dial

-hp- 207A Audio Sweep Oscillator—continuous output 20 cps to 20 KC—flat response, low distortion—may be motor driven or coupled to recording device

SPECIFICATIONS

Frequency Range:
20 cps to 20 KC, covered in one range.

Accuracy:
±4% including changes due to warm-up, aging components, tubes, etc.

Dial:
Six-inch diameter dial calibrated over 300° of arc.

Frequency Response:
±1 db entire frequency range.

External Frequency Control:
¼-inch shaft, extending from rear of instrument, rotation approximately 150° for full frequency coverage.

Output:
10 volts into 600 ohm rated load, balanced or 1 terminal at ground.

Output Control:
Decreases level continuously by more than 40 db.

Distortion:
Less than 1% over entire frequency range.

Hum Voltage:
Less than 0.1% of rated output. Decreases as output is attenuated.

Power:
115/230 volts, ±10%, 75 watts.

Dimensions:
Cabinet Mount: 7½" wide, 11½" high, 15¼" deep. Rack Mount: 19" wide, 7" high, 12½" deep.

Weight:
Approximately 25 lbs.

Price:
$275.00

Data subject to change without notice

Here at last is a low cost, high quality oscillator providing the time-saving convenience of continuous single-sweep frequency coverage from 20 cps to 20 KC. The instrument has high waveform purity, constant output, high stability and dial calibration which is essentially logarithmic. Band switching and resulting transients are eliminated. A flexible 10 volt output can be used balanced or with one side grounded.

Model 207A may be swept by hand, motor driven, tuned remotely or coupled to a recording device by means of a shaft extended through the rear of the cabinet.

Priced at just $275.00, this new *-hp-* oscillator is an outstanding value and particularly convenient for such audio tests as speaker frequency response and amplifier flatness, measuring characteristics of filter networks, complex coupled systems and industrial transducers, or automatic response measurements where response is recorded or viewed on an oscilloscope.

HEWLETT-PACKARD COMPANY

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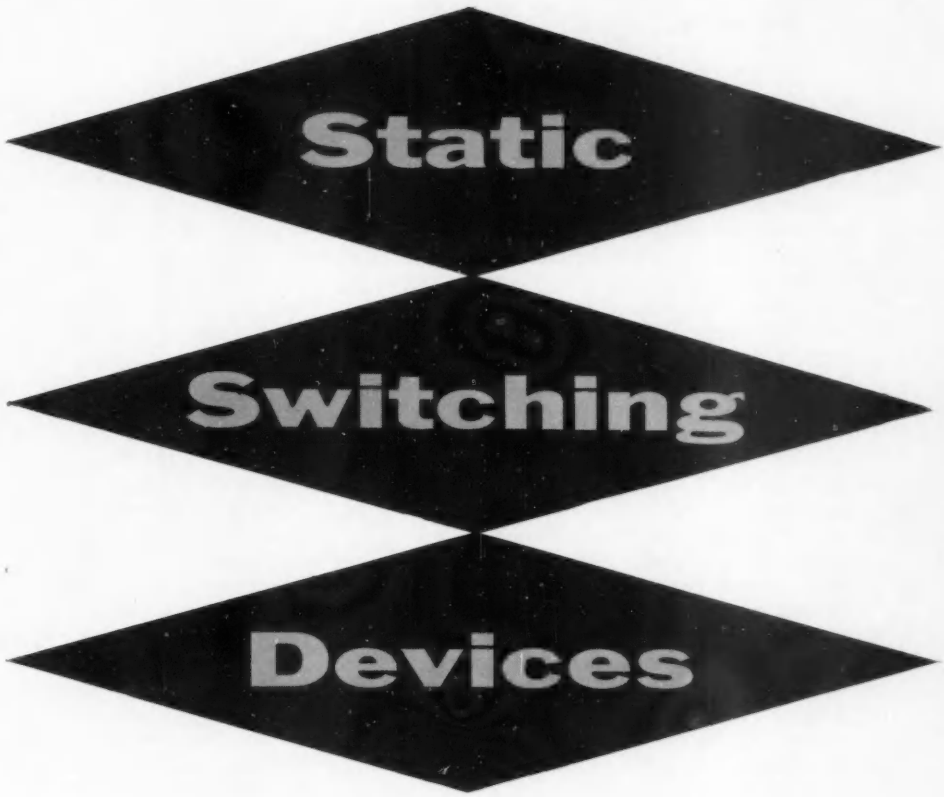
Field engineers in all principal areas

hp ELECTRONIC MEASURING INSTRUMENTS



NEW TOOLS FOR INDUSTRIAL CONTROL

ROBERT A. MATHIAS

Department of Electrical Engineering, Carnegie Institute of Technology

Whether controlling a machine tool, a materials handling system, or a flow process, industrial control engineers cannot afford to overlook the possibilities of increased reliability, higher operating speeds, and reduced maintenance and downtime inherent in static switching systems. Professor Mathias brings to CONTROL ENGINEERING a thorough study of these interesting and controversial new techniques, from the unbiased position of an independent consultant—he reviews basic logic and the fundamentals of magnetic and semiconductor switching devices, surveys commercially available equipment, provides analytical case studies of a wide variety of applications, gives system design tips, and takes a look at the cost picture.

Electromechanical relays grew out of the concept that switches could be opened and closed by low-powered independent control signals. These remotely-operated switches were originally used in single-motor control and other similar applications. However, with the increased demand for automatic features, switching systems grew in complexity to the point where today many racks of relays control an automotive transfer machine or a complex materials handling system. Space, reliability, and maintenance are problems today; what will they be in the future?

Static power-modulating devices such as magnetic core units and semiconductors were originally intended to improve the reliability and performance of analog or proportional control systems. It was soon found, however, that these static analog devices could be modified, in many cases, to operate as switching control devices, thus assuming many of the desirable characteristics of electromechanical relays: bi-stability, with two output states corresponding to two input states; insensitivity to changes in other components; and amplification, with output several times input.

This led to the commercial development of industrially oriented static switching devices and systems, which on one hand filled a need—caused by the increasing complexity of electromechanical relaying systems—and on the other hand provided a solution—adapting static power-modulating devices for switching-type service. Applications particularly suited for static switching control are characterized by one or more of the following requirements: extreme reliability, reduced and simpler maintenance, high speeds with many switching operations, reduced space requirements, and safe operation in hazardous atmospheres.

Electromechanical relay contacts have a finite life; thus relay life can be numbered in terms of operating times, even though this number may be up in the millions. In contaminated atmospheres the contacts tend to become grimy and dirty, or, after a large number of operations, pitted. These conditions may cause relay failure which could prove critical if a large production line or system is dependent on the reliability of this element. Striking testimony to this is the statement by one of the top production engineers of Chrysler that down-time on one of their main automotive lines costs about $1,000 a minute.

However, the electromechanical relay is not becoming obsolete. Cost is one reason. In simple systems or in systems with many outputs (motors, solenoid valves, etc.) and few inputs (limit switches, pushbuttons, etc.), the first cost of a static switching system is often many times that of a conventional relay system. In most of these cases, static switching would only be considered if reliability were of overwhelming importance. Besides, manufacturers are continually improving their relays and the manner in which they are used. Hermetic sealing, reduced size, and improved contact materials are steps in this direction; one manufacturer advocates a technique of impressing a high-voltage, high-frequency pulse across relay contacts to break down the film that forms in contaminated atmospheres. There are other reasons, too, for the continuing popularity: most users state that the majority of system failures occur in the limit switches rather than in the logic or switching circuitry—so why pay the additional price for reliable static switching devices if other portions of the system fail first anyway? and manufacturers of systems that must fail safe (for example, press-control circuits, where an improper failure may result in injury to an operator) have found that the cross-wiring and bias connections necessary in static-switching systems make it extremely difficult to design a system that will fail safe under any conditions.

Improved contactless limit switches and pushbuttons (discussed later in the article) and further engineering investigation of the fail-safe problem will probably reduce these difficulties, but in any event it appears that neither type of switching device will eliminate the other and that they will continue to be used side by side. Thus, relays are used to handle infrequent switching operations such as faults or power line failures, or where high-power circuits must be completely interrupted, such as in large motor starters.

It should be noted that static switching devices are standard industrial control elements, available in packaged functional form, and are not to be confused with similar elements used in large-scale digital computers. The usual large-scale digital computer has the ability to count, to store large quantities of information, and to perform logic decisions. Thus far industrial static-switching systems have been called on primarily for basic logic decisions and only infrequently for counting and information storage. But as pointed out later, these possibilities should not be ignored.

The resistance to the use of static switching systems has been based primarily on the following points: high cost—primarily of output amplifiers and available proximity limit-switches; large size and unsatisfactory performance of available input devices—proximity limit-switches and pushbuttons; the different and more difficult process required to design static switching systems; repairs beyond the ability of the average maintenance

TABLE 1

CHARACTERISTICS OF INDUSTRIAL SWITCHING DEVICES

	Type of device	Reliability and life	Circuit and logic complexity, and power supply requirements	System engineering complexity	Maintenance requirements	Size and weight	Speed of response	Input device requirements	Output devices and associated problems	Cost and availability	Applications
NONSTATIC DEVICES	Electromechanical relays	Relatively poor reliability in severe mechanical or corrosive environments; life limited by number of operations	Medium complexity; no special power supplies required	Medium	Heavy maintenance if operating rate is high	Medium	Relatively slow	May be operated directly by a wide variety of input devices	Most output equipment can be driven directly	Immediately available in numerous varieties; reasonably priced	Unless hermetically sealed, cannot be used in dirty or explosive atmospheres, otherwise widely applicable
	Electronic tubes	Poor reliability in severe mechanical environments; life limited, particularly by filament burnout problems	Filament power supply required	Medium	Heavy maintenance for multiple-tube installations	Medium	Fast	Additional components may be required to match inputs for proper operation	Amplification usually required to drive industrial-type output devices	Widely available; reasonably priced	Limited industrial applications to-date because of environmental and reliability problems
STATIC DEVICES	Westinghouse Cypak system (based on Ramey magnetic-amplifier circuits)	Very good record of reliability in service; life independent of operations	Special power supply required	About the same as relay circuits; possibly easier to debug	Minimum maintenance required	About same as relay system	Responds in ½ cycle of supply frequency. No moving parts, so magnetic core sets inherent limit	For conventional input devices special components are required to match voltage levels; improved proximity switches, etc., will alleviate this problem	Require relatively expensive power amplifiers to drive most industrial-type outputs	Cost depends on circuit complexity and relative number of output amplifiers since power supply cost is almost constant for most systems, and switching is performed at low power levels; usually first cost is higher than relays, but this may be more than offset by reduced maintenance and downtime	Very wide range, including those in severe mechanical environments and extreme atmospheres
	GE Industry Control static system (based on conventional magnetic-amplifier circuits)	Should be as reliable as magnetic amplifiers; life independent of operations	Special power supply required	Probably slightly more complex than Cypak for multipurpose units unless logic possibilities are well catalogued	Minimum maintenance; modules have monitor lights to aid in maintenance	About same as relay system	A few cycles of supply frequency	Same as Cypak	Same as Cypak		Same as Cypak
	GE General-Purpose Control static system (based on magnetic-amplifier circuits with pulse power supply)	Should be as reliable as magnetic amplifiers; life independent of operations	Special power supply required; novel AND circuit	About the same as Cypak	Minimum maintenance; monitor lights can be clipped on modules	About same as relay system	Responds in ½ cycle of supply frequency	Same as Cypak	Same as Cypak		Same as Cypak
	Westinghouse Universal Switching Amplifiers (based on conventional magnetic-amplifier circuits)	Should be as reliable as magnetic amplifiers; life independent of operations	No special power supply required	Considerable engineering time required for system design, but resulting circuit is often much simpler than above equipment	Minimum maintenance	System is often smaller and lighter than others	A few cycles of supply frequency	Same as Cypak	Output power is sufficient to directly drive many types of output devices	Cost per unit is higher than in above systems, but fewer units are usually required for comparable circuit	Probably not well-suited to systems requiring considerable sequencing
	Transistor units, such as Westinghouse NOR circuit	Reliability not proved but should be very good; life independent of operations	Usually requires special power supply, although power requirements are much lower than for above systems	About the same as Cypak	Should require minimum maintenance	Much smaller and lighter than any of above	Fairly fast	Same as Cypak	Require relatively expensive power amplifiers to drive most industrial-type outputs	Not commercially available; cost should be comparable to that of other static systems	Not assessed yet; should be innumerable

WHAT A USER THINKS OF CYPAK

This is the latest information concerning our own experiences and reactions. Experience of Process Development Section with Cypak up to Nov. 15, 1956

I. Torus vane-loading machine

A batch of eight vane-loading machines were designed and built by Process Development Section for Detroit Transmission Div. during 1955. All eight were equipped with relay-type control panels. The final machine had, additionally, a Cypak control panel.

The sequence of operation and relay circuit were supplied to Westinghouse, which designed and built the Cypak panel. Without finding it necessary to refer back to Westinghouse, PDS made some sequence changes and combined the two systems so that – using the same limit switches and pushbuttons – the machine could be plugged into either the Cypak or the relay panel.

The Cypak unit was placed in production Nov. 28, 1955, and to-date, has fed just over 8 million vanes.

There have been three failures on the unit:

1. After 4 million vanes a rectifier failed – cause unknown. It occurred during severe thunderstorms and possibly could be due to a surge from a lightning strike on the power lines.
2. After 5¼ million vanes an outgoing wire from the panel came loose at a terminal board – presumably due to vibration.
3. After 6 million vanes a wire in a toroidal core broke at the point of soldering to the binding post, presumably due to vibration. The solder had run up the wire about ⅛ in. and the break occurred at the tip of the solder.

It should be noted that this panel was made from the original type units; had the encapsulated units been available and used the third failure would not have occurred.

The Cypak panel is still running in production.

No detailed figures are available regarding the failures on the other seven machines. However, Detroit Transmission informs us that these failures have been so frequent that serious consideration is being given to equipping these other vane loaders with Cypak.

The operating performance of the Cypak on the vane loader is the best control performance we have seen. Many claims are heard of relay and limit switch life varying from 10 million to 50 million operations, but when used on production, actual life varies from 100,000 up to about 5 million operations.

At present the life of the rectifiers appears to be the doubtful factor in Cypak, but 30-milliamp rectifiers operating at 5 milliamps should have a reasonably long life – Westinghouse claims up to 10 years, but until we have more experience, we would anticipate at least three years.

II. Disc assembly machine

Process Development Section has designed and built a disc assembly machine controlled by Cypak. In this case the components were purchased from Westinghouse but the circuit design, building, and debugging were done entirely by PDS.

a. Design was handled by a junior engineer, who had not previously been exposed to Cypak. Total electrical design and debugging time was approximately double that which he would have taken for relay control, but this included his time for reading up on and becoming familiar with the new control. It is believed that once a designer is familiar with logic circuits, design time will be less than that with relay circuits. It was anticipated phasing of elements might cause some difficulty, but this did not produce any worries at all.

b The control panel (using old-type elements) was built in our own shop, and processed through as a normal build job with no supervision from Engineering Dept. Wiring was 100 percent correct when checked.

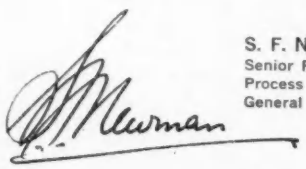
c. Debugging the control presented no additional problems. As was expected, there was an initial feeling of strangeness due to lack of visual and audible action from relays, but a debugging system was quickly devised.

d. Reaction of electricians and engineers was favorable; we would not anticipate any justified opposition from users' personnel.

III Conclusions

It is believed that static control will be universally accepted in the future. Although it may require further development, there should be no hesitation in using it now because:

a. Personnel will be gaining experience with it.
b. Greater use will mean increased production, hence lower cost.
c. Use in production provides an enormous background of test and hastens development.
d. Even in its present form it is still far more reliable than relay-type control.



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man; the difficulty of making quick circuitry changes in the field without revising the complete system; and the questionable interchange of new components for old when repairs must be made. Certainly the first two points are legitimate complaints, recognized by manufacturers of this equipment as well as by the users, and much engineering time and effort is being devoted to them, with some success already realized and more just around the corner. But according to experienced users, the other points are based more on bias than on fact. For a quick rundown on one user's experience with, and opinion of, Cypak (Westinghouse Electric Corp.) see the special boxed-off section "What a User Thinks of Cypak" (opposite page), remembering that the General Motors Corp. is one of the world's largest users of electromechanical relays.

Though the field of industrial static switching is only a little more than two years old, applications range across the board: many types of machine tools, food and chemical processing systems, conveyor and warehouse materials handling systems, quality and acceptance control systems, automatic assembly machines, etc. Many examples of these applications are discussed in detail in a later section.

Digital control using static devices

Although most of the work in the field of static switching industrial control is concerned with the development of systems that will more or less replace conventional electromechanical relaying systems, other areas should not be overlooked. These static logic elements can perform all of the functions required in a digital computer and as such could be combined into small (in capacity) special-purpose digital computers or into digital controllers to perform some of the jobs now being handled by analog equipment. The examples discussed later will illustrate how some of this thinking is now entering into the design of complex systems, though cost, size, and industrial unreadiness are preventing large-scale penetrations. However, with the introduction of transistor switching elements (packaged for factory use) and the reduction in costs, small, special-purpose digital computers and controllers can be assembled from reliable, industry-type components.

As accuracy requirements become more rigorous, and the information that must be handled in a given time interval increases, analog systems tend to become complex and sometimes impractical. Accuracies of one part in 10,000, for example, are almost impossible with analog techniques. But if this value is separated into four digital channels, each corresponding to one of the four decimal digits of the value, each channel would only need to be accurate to about one part in ten to achieve the same overall accuracy. And this system could be made truly digital if each of these so-called channels had only ten possible stable states. Practically, however, it is much easier to build the logic components with only two possible stable states (ON-OFF, for example) even though it means more components. Bi-state or binary components can usually tolerate large variations in input signal and still operate faithfully. If the above value is expressed on a binary basis, approximately 13 binary digits are required to give the same accuracy. If greater accuracy is required, additional logic units can be added (assuming the input and output devices can properly provide and use the information). In short, in processing the sheer bulk of information required by high accuracies or complex systems, digital methods appear to have many advantages.

One of the most important of these advantages is that information is processed in the form of the basic unit of information—the bit. Large variations in environmental conditions and aging of components do not reflect in the desired state of the bi-state logic elements. Digital systems are also well-suited for controlling automatic sequencing operations (the complex relay panel that automatically sequences a transfer machine through its operations is actually a digital system, although it is not often thought of as such). These operations require not only elements that act upon the presence of a particular combination of inputs, but also ones that act according to the sequence or history of the inputs. This means that to make proper use of later information, the system must remember information given to it previously. The storage and shifting of information in an internal memory brings to industrial control systems the important attribute of a stored-program digital computer.

If not carefully designed, a digital logic system can produce highly illogical results if one or more of the logic elements fails to operate as directed. As pointed out previously, with electromechanical relays these failures usually result from mechanical shock or vibration, or wear or dirt at the contact surfaces. Vacuum-tube switches have no contact problems, but they do run the chance of filament burn-out. Static devices, however, both from a theoretical and service viewpoint, appear to have lives independent of the number of operations or the time in service. Table 1 compares the characteristics of various switching devices.

Static is used here in the sense that there are no active mechanical or thermal parts, although certainly the components are not electrically static. Because of their static nature, solid-state devices—both magnetic and semiconductor—can be packaged and mounted to be quite rugged and insensitive to extremes in environment. As pointed out later, this is leading to a healthy competition between manufacturers of this equipment.

A SHORT COURSE IN BASIC LOGIC

Before examining the actual circuits used in static-switching devices and systems, it is best to take a general look at the logic used in processing information, since a knowledge of fundamental logic is basic to the design of switching systems. Combinational logic will be examined first. This type of logic produces outputs that depend only on the combination of input signals, and not on the sequence in which the inputs are applied. The primitive combinational logic functions are AND, OR, and NOT.

Figure 1 shows two different representations of the AND function. Figure 1A is a relay circuit with the normally-open contacts of relays, *A*, *B*, and *C* in series. The output X_1 is obtained only if *A* and *B* and *C* are energized and their contacts closed. The AND function can also be thought of as a relay with a number of separate windings, designed so that the single contact does not close until all of the windings are energized. This is shown in Table II, which lists the eight possible combinations of the inputs *A*, *B*, and *C*. The 0 values in the table represent open contacts or the absence of signals, and the 1 values represent closed contacts or the presence of signals. Thus, X_1 is present only when each of *A* and *B* and *C* are present. Attention should be paid to Table II, since, as will be seen throughout the article, a tabulation of input and output combinations is extremely useful in designing switching systems.

A fundamental aid in analyzing and simplifying logic circuits is Boolean (or switching) algebra[2, 3]. This algebra is quite simple since it considers each variable as having only two possible values, 0 or 1. The multiplication sign is used for the AND operator in Boolean algebra since it has about the same properties as the usual multiplication operation. For example, an open switch in series with either an open or closed switch still yields an open circuit (similar to multiplying by zero). Thus,

$$0 \cdot 0 = 0 \cdot 1 = 0 \cdot X = 0 \qquad (1)$$

where X is a general switch with either a 0 or 1 state.

It follows that a closed contact in series with a closed contact forms a closed circuit, and that a closed contact in series with a general switch X gives an open or closed circuit depending on whether X is open or closed. Two switches of X operated by the same signal operate as one switch of X, etc.

$$1 \cdot 1 = 1, 1 \cdot X = X, \text{ and } X \cdot X = X \qquad (2)$$

Thus, the function X_1 in Figure 1 is

$$A \cdot B \cdot C = X_1 \qquad (3)$$

and X_1 is 1, according to the properties of Equations 1 and 2, only when each of *A*, *B*, and *C* are 1.

The OR function is another basic logic operator. Figure 2A shows a relay circuit with normally-open contacts *A*, *B*, and *C* in parallel. Thus, the output X_2 exists if any one or more of the contacts *A* or *B* or *C* are closed. Figure 2B shows the functional representation of OR, and Table II indicates that X_2 is 1 if either *A*, *B*, or *C* is 1.

The plus sign is the Boolean algebra operator for the OR function because it has many of the usual addition properties. Many of the useful Boolean identities can be easily remembered by visualizing the corresponding contact network. For the OR function there is only one case for which there is no output, that is, if all the contacts are open. Thus,

$$0 + 0 = 0, \qquad (4)$$

and

$$0 + 1 = 1 + 1 = 1 + X = 1 \qquad (5)$$

TABLE II

INPUT AND OUTPUT COMBINATIONS

INPUTS			OUTPUTS								INVERSE INPUTS		
A	B	C	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	$\overline{A}$	$\overline{B}$	$\overline{C}$
0	0	0	0	0	1	0	D	Q	1	1	1	1	1
1	0	0	0	1	0	0	0	0	1	0	0	1	1
0	1	0	0	1	1	0	0	0	1	0	1	0	1
1	1	0	0	1	0	0	D	0	1	0	0	0	1
0	0	1	0	1	1	1	D	0	1	0	1	1	0
1	0	1	0	1	0	1	1	1	0	0	0	1	0
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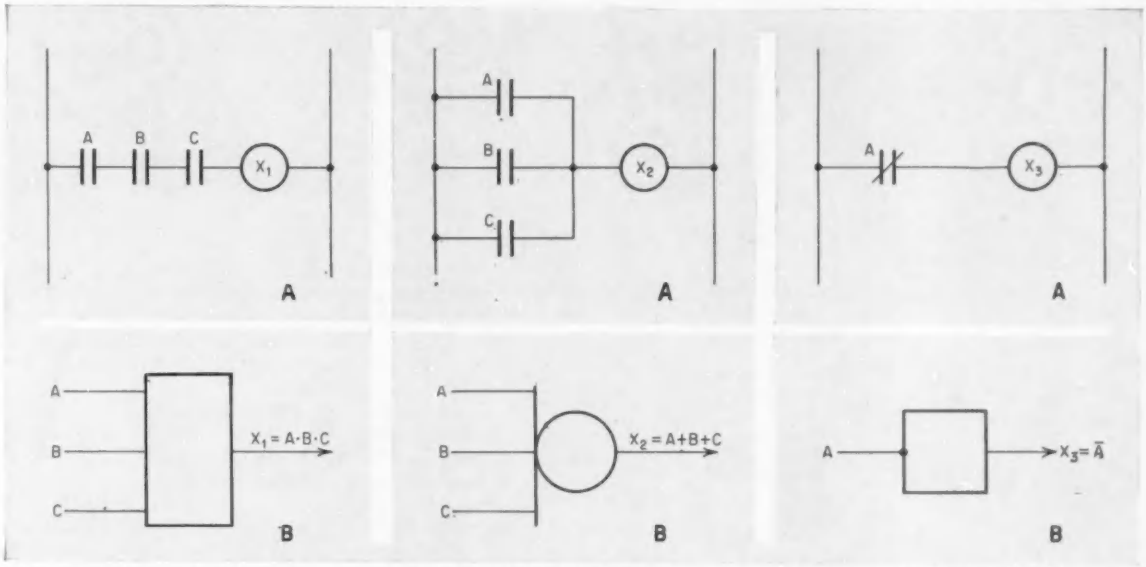


FIG. 1. THE AND LOGIC FUNCTION.
A. Relay AND circuit
B. Symbolic representation of AND.

FIG. 2. THE OR LOGIC FUNCTION.
A. Relay OR circuit.
B. Symbolic representation of OR.

FIG. 3. THE NOT LOGIC FUNCTION.
A. Relay NOT Circuit.
B. Symbolic representation of NOT.

Note that one plus one is still one. Also, a general contact X in parallel with a like acting contact or an open contact still gives the same function X.

$$0 + X = X + X = X \tag{6}$$

Then, X_2 in terms of A, B, and C is

$$A + B + C = X_2 \tag{7}$$

The NOT operator completes the group of three primitive logic functions. Figure 3A shows a relay NOT circuit with a normally-closed contact A. The output X_3 is present only when the contact A is NOT energized. Thus, the NOT function gives the inverse or negative of the output. If the input is in the 0 state, the output is 1 and vice versa. The logic operator for the NOT function is a bar above the function of which the inverse is being taken. Some useful NOT identities are

$$\bar{0} = 1, \bar{1} = 0, X \cdot \bar{X} = 0, \text{and } X + \bar{X} = 1 \tag{8}$$

Table II shows the NOT functions $\bar{A}$, $\bar{B}$, $\bar{C}$, and X_3.

The identities given for the three basic logic functions are useful in simplifying the logic for specific conditions. If all possible input combinations are listed as in Table II, and the desired output conditions specified, a direct translation into Boolean algebra is possible. As an example, note the output X_4. It is to be present for three of the eight possible input combinations. Just as X_1 was present for A and B and C, so X_4 is present for each of ($\bar{A}$ and $\bar{B}$ and C) or (A and $\bar{B}$ and C) or ($\bar{A}$ and B and C). In switching algebra, that is

$$\bar{A}\bar{B}C + A\bar{B}C + \bar{A}BC = X_4 \tag{9}$$

To simplify the logic for X_4 even further, a term is added that does not change the logic. This would appear as an additional condition for the presence of an output, but it must be the same as one of the existing conditions if the logic is not to be altered. The last identity in Equation 6 indicates that this can be done. Rewrite Equation 9 with the first term, $\bar{A}\bar{B}C$, repeated as the last term, and with the C which is common to each factored out.

$$(\bar{A}\bar{B} + A\bar{B} + \bar{A}B + \bar{A}\bar{B})\, C = X_4 \tag{10}$$

Now $\bar{B}$ may be factored from the first two terms and $\bar{A}$ from the last two terms.

$$[(\bar{A} + A)\, \bar{B} + \bar{A}(B + \bar{B})]\, C = X_4 \tag{11}$$

The last identity in Equation 8 shows that a function OR its inverse is 1. And from the second identity of Equation 2, it is seen that 1 AND a function is the function. Equation 11 reduces to

$$(\bar{B} + \bar{A})\, C = X_4 \tag{12}$$

This same reduction can be made pictorially by using a switching network. Figure 4A shows the switching network for the initial given conditions. The conductor on the left can be connected to the one on the right in at least one of three ways. These three ways correspond exactly to the 1 states of X_4. The A is a normally-open contact and the $\bar{A}$'s are normally-closed contacts, all on relay A. These correspond to the 1 and 0's of A for the three 1's of X_4. Figure 4B is the circuit given by Equation 10, and Figure 4C by Equation 11. The final circuit of Equation 12 is shown in Figure 4D.

Table II can be used for another type of logic condition. This is shown by X_5, where three of the output conditions are represented by D's rather than by either 0 or 1. A D is a "don't care" condition. This means that that particular input combination is either one for which the designer doesn't care whether its output is 0 or 1, or is one that could never occur for the system. The value of stating and using "don't care" conditions, if they exist, is that a careful choice of either a 0 or 1 for each D can usually simplify the final logic function, assuming no outputs for each D condition. This simplification can be readily done with the aid of Karnaugh

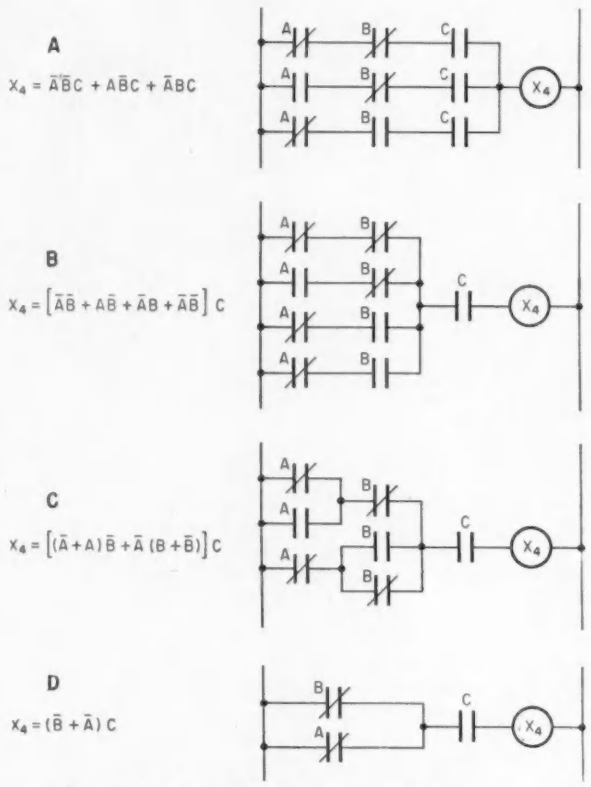


FIG. 4. The step-by-step simplification of a switching circuit.

maps[4]. In the case of the logic function X_5, if none of the D conditions is used, then an output is wanted only for ABC or $\bar{A}BC$. This specific set of conditions is given by X_6 in the table. But the simplest relay schematic that will provide the logic required by X_6 is that shown in Figure 5.

By using one of the "don't care" conditions for X_5, the switching circuit can be further simplified while still satisfying the conditions of X_6. The D condition for inputs ABC is used as a 1 state. This makes X_5 the same as X_4. Figure 4D definitely shows that this additional output condition permits a simpler circuit than Figure 5.

There is still another way in which Table II can simplify the process of translating desired output states into switching circuits. This involves the use of the inverse of switching functions. A typical example is illustrated by output function X_7, which has an output for all but two of the input combinations. This makes it much easier to express the cases for which no output occurs. The methods already discussed can be used to find the inverse function X_6, which has an output only for the two conditions for which X_7 does not. After determining X_6, a simple switching algebra manipulation gives its inverse. First X_6 is written as

$$ABC + A\bar{B}C = (A\bar{B} + \bar{A}B)\,C = X_6 \qquad (13)$$

But since X_6 is the inverse of X_5, it must be inverted. To invert X_6 (or any general function), the roles of the AND and OR functions are interchanged, and each component in the function is inverted. That is, A is inverted to $\bar{A}$ and $\bar{A}$ is inverted to A. X_6 is inverted as follows:

$$X_7 = \bar{X}_6 = \overline{(A\bar{B} + \bar{A}B)\,C} = (\bar{A} + B)\,(A + \bar{B}) + \bar{C} \qquad (14)$$

By applying the third identity of Equation 8, X_7 can be rewritten as

$$X_7 = AB + \bar{A}\bar{B} + C \qquad (15)$$

The AND, OR, and NOT logic functions are the primitive or basic logic units, and any other logic function can be developed from these. If there is no feedback to any of the inputs of the units providing the feedback, then the output states are the result of the combination of input signals alone, and are in no way dependent on the sequence of the inputs. However, as more automatic capabilities are required of the newer switching systems, more memory of the sequence of inputs is necessary. Storage of this information can be done internally by memory units, flip-flops, latching relays, etc., or it can be done external to switching circuit. Cams, mechanical latches, and similar external devices can store some information, but not as much as punched cards or tape and magnetic tape.

Figure 6A shows an internal memory circuit that can remember one kind of thing. That is, relay coil Y is energized if the ON button has been pushed since the OFF button was pushed last. Note that unlike any of the switching circuits considered up to now, the sequence of events in this circuit is important. Also note the feedback, which is not unlike that of an electronic flip-flop. If relay Y is energized, its normally-closed contact opens the circuit to the coil of relay X, and vice versa. Only one relay can be energized at a time. Neither relay is energized if both buttons are depressed.

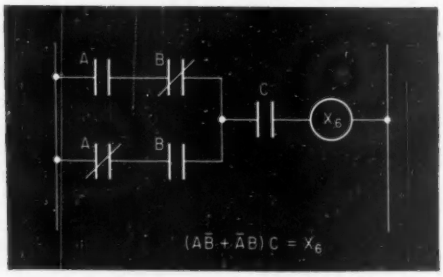
The switching circuit in Figure 6B performs the same function as that in Figure 6A, though with different switching arrangements. In fact, this is an example of the use of the inverse of an inverse function to achieve the same results. Z is the inverse of X, so that the contact controlled by Z is normally open, whereas the one controlled by X was normally closed. This means Z is energized where X was deenergized, and vice versa. The ON and Y contacts in Figure 6B are the inverse of those in Figure 6A, since they are changed to normally open from normally closed and to parallel from series.

Since parts A and B of Figure 6 are equivalent, the switching algebra for the output Y of either one is

$$\bar{F}(N + Y) = Y \qquad (16)$$

where N and F are the presence of the ON and OFF inputs respectively. The equation states that the output Y is present whenever the OFF state F is not present, and whenever the ON state N is present

FIG. 5. Relay schematic for indicated logic function.



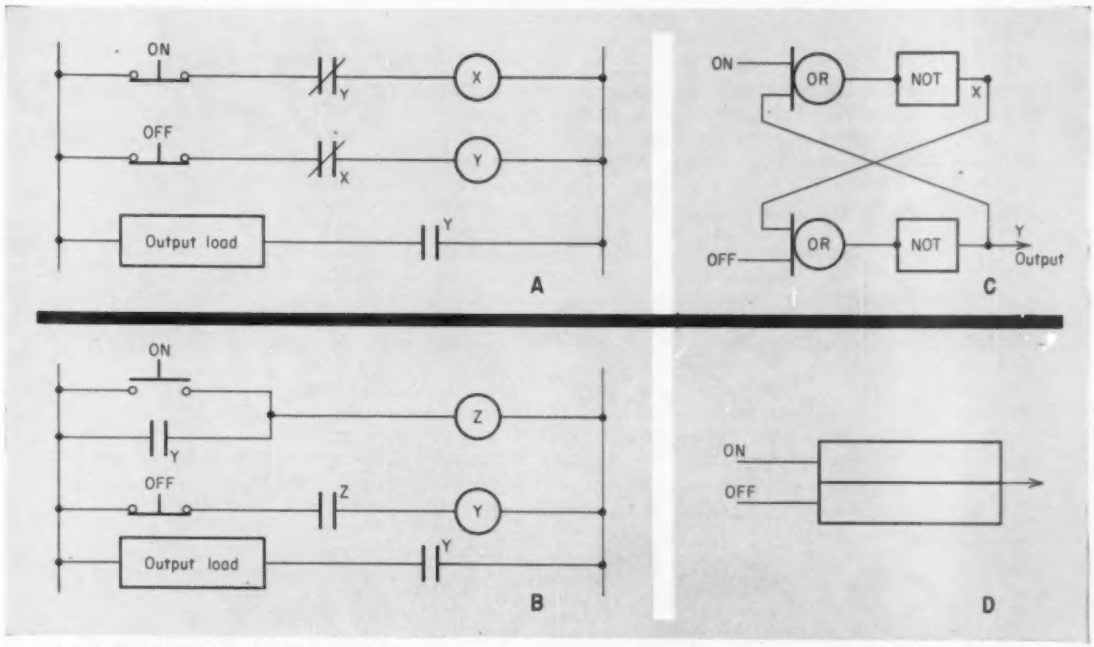


FIG. 6. THE MEMORY LOGIC FUNCTION.

A. Relay memory circuit.
B. Memory circuit derived by taking inverse of inverse function; it performs the same as A.
C. Memory circuit derived by combining two two-input OR elements and two NOT elements.
D. Symbolic representation of memory.

or the output Y is already present. The previously mentioned feedback situation is evident in Equation 16, since the logic function that determines the output is a function of that same output. Figures 6C and 6D are symbolic representations of this memory circuit. A note of caution: switching algebra must be very carefully applied and interpreted when sequential circuits are being considered[8].

HOW STATIC SWITCHING DEVICES WORK

An understanding of how static switching devices work can help the designer in both the logical and electrical design phases of complete static switching systems. Present static switching elements are primarily magnetic-core units and semiconductor devices. Those discussed here include diode circuits, reset-type magnetic-amplifier circuits, bistable circuits using conventional magnetic-amplifier configurations, pulse-type magnetic-amplifier circuits, and transistor and combination transistor-magnetic circuits. Although these are discussed here generally, each of the commercially available systems is based on one or another of these fundamental approaches.

Diode switching circuits

Simple static switching units can be constructed using only semiconductor diodes or rectifiers. Figure 7 shows a diode AND circuit and a diode OR circuit. In the AND circuit, Figure 7A, the three interconnected rectifiers are fed a positive supply voltage through a resistor. The A, B, and C inputs to the AND circuit are present when a positive voltage is applied to each respective input terminal. This type of AND circuit also requires that each of the inputs present a low-impedance path to the negative or common side of the circuit when the inputs are in the OFF state. This low-input path to ground is required so that the output X_1 is not present if any one of ABC is at zero potential. If, for instance, A is at zero potential with respect to the common lead, then the low-impedance path to the common lead through the rectifier in input path A provides a path to ground for the current flowing through the supply-voltage resistor. The forward conduction through the diode provides very little voltage drop in the path to ground, and thus there is no output, or the output is said to be in the OFF state.

However, if input signals (positive potentials) exist at all three of the input terminals, there is a high-impedance path to ground through the input terminals because of the high back-resistance of the rectifiers, and current flows from the positive dc supply, through the dropping resistor, and out the output terminal at X_1. Because of the need for a conduction path to ground when one of the signals is not present, the input signals cannot come from switches that physically make and break contacts.

In the diode OR circuit, Figure 7B, the output X_2 exists if inputs (positive potentials) are present at either A or B or C. Unlike the AND circuit, the OR circuit does not require an external supply voltage lead or the dropping resistor, and the input paths need not present a low impedance to the common lead if any one of the input signals is not present.

In theory, complete logic systems can be made up from diodes only, although there is no possibility of amplification in these circuits. Thus, if many units

using only diodes are combined into logic circuits, the signals are attenuated and tend to degenerate. In industrial control practice, one or two cascaded stages is usually the practical limit.

Reset-type magnetic-amplifier circuits

The "Ramey" magnetic-amplifier circuit[6] is particularly suited for switching service. Its output, in common with other magnetic-amplifier circuits, is limited by saturation to definite states. This saturation effect in the output characteristic results directly from the saturation characteristic of the magnetic-core material used in high-performance magnetic amplifiers. This core material has a rectangular-shaped hysteresis loop, with sudden saturation at either extreme of flux change on the hysteresis loop.

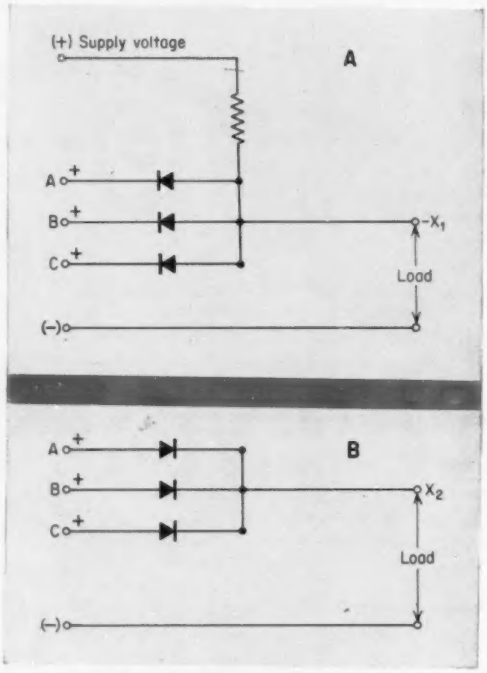


FIG. 7. SEMICONDUCTOR-DIODE LOGIC CIRCUITS.
A. Diode AND circuit.
B. Diode OR circuit.

The basic Ramey circuit, Figure 8A, uses two separate circuits, magnetically coupled by the sharply saturating core. The right-hand circuit on this diagram is called the gating circuit, since it gates or switches the output ON or OFF. The rectifier γ_1 in the gating circuit permits current to flow in only one direction. The coil polarity, and the relative directions of the rectifiers γ_1 and γ_2 cause the core to be reset, i.e., driven in the negative direction, opposite to the action of the gating circuit. Thus, the reset circuit on the left can only reset the core.

Another feature of the Ramey circuit that well suits it for switching service is that its output occurs exactly one-half-cycle after the input.

The basic Ramey circuit is shown in Figure 8A. E_I, the input voltage, is a low-power-level signal, which, because of the inherent amplifying property of the circuit, can control the output voltage E_o at a much higher power level. Figure 8B shows the output characteristic of this circuit as average output voltage versus average input voltage. With a negative input voltage there is no output, but as the input voltage starts to go positive, the output increases proportionately until it reaches a definite maximum value—actually the value of the gating supply voltage. Thus, the maximum average output voltage is reached when the output voltage appears for the whole gating half-cycle.

The usual mode of operation of the Ramey circuit is as follows: After the gating half-cycle, the flux level on the core hysteresis loop is left at positive saturation. The reset half-cycle begins, and the core resets, when E_R is negative and greater than E_I. The rate of reset is determined by the difference between E_R and E_I. The circuit is normally designed so that if E_I is zero, E_R can completely reset the core during the reset half-cycle. Complete resetting means bringing the flux level down to negative saturation. If the gating half-cycle does begin with the core at negative saturation, then the gating voltage, for the normal design, takes till the end of the gating half-cycle to drive the flux to positive saturation. No load current flows, except for the core exciting current, since all of the gating supply voltage, E_G, is absorbed across the winding N_G, while the flux level is increasing.

But if the input voltage, E_I, is greater than the reset supply voltage, E_R, at each instant of the reset half-cycle, no reset occurs. This is because the excess of the input voltage over the reset voltage appears as a back voltage across the reset rectifier γ_2. In this situation, practically no voltage appears across the reset turns, N_R, and the flux level does not change. On the following half-cycle, the gate starts at positive saturation and load current flows immediately. This is the full output situation shown in Figure 8B.

For switching service, the only allowable input voltages are zero and values greater than the reset supply voltage, E_R. Thus the amplifier can only have either a 0 or 1 output state. In logic circuits where many stages must be cascaded, the Ramey circuit must be modified to give optimum performance.

One reason for modifying the Ramey circuit is that the input voltage must present a low source impedance if the output is to be accurately controlled. In the normal circuit, an input signal from a high-impedance source permits reset even when the signal voltage is zero because of the magnetizing current flowing through this high impedance, which appears as a voltage drop. This reset is, however, undesired. The situation can be corrected by adding a rectifier γ_3, as in Figure 8C. At first glance it would appear that the magnetizing current could not flow through γ_3, since it is placed to oppose the current flowing through γ_2. Actually, though, the additional negative supply voltage and the resistor are designed so that the net current flow through γ_3 is always positive, and the magnetizing current flowing through γ_2 is the smaller portion of the total current flow. This low forward drop through γ_3, which looks like a low source impedance for the magnetizing current, prevents full reset with no input signal.

When the input voltage is large enough to give

full output, it is greater than the reset supply voltage E_R at every instant of the reset half-cycle. During this interval, point a is positive with respect to point c. This causes a back voltage across γ_2, and no resetting magnetizing current can flow. Since point a is positive with respect to ground, γ_5 also has a back voltage across it. This means that the input must supply the leakage through γ_5, and the current flowing through the resistor to the negative supply.

The rectifier γ_5 in the gate circuit makes sure that the output cannot go positive with respect to ground during a gating half-cycle when the core starts from negative saturation. This makes it possible for the zero output level to be even slightly negative, because even though the gate supply voltage E_G appears only across the gate winding, the magnetizing current during this interval is flowing through gate rectifier γ_1, and some small positive voltage could appear across the load if it were not for the forward drop across rectifier γ_5. This forward drop supplies a small negative voltage, and makes sure that the output will not be positive when this unit drives another similar unit unless an ON state is desired.

The supply voltages for the circuit of Figure 8C are phased oppositely; that is, the negative dc supply voltage for the gating circuit has a voltage appearing on the half-cycle when no negative dc voltage appears for the reset dc supply. The negative dc supply voltage in the gating circuit occurs on the gating or output half-cycle, while the reset negative supply voltage appears on the other or reset half-cycle.

The gate supply voltage is made about twice the magnitude of the reset supply voltage so that the output of one unit can always reset any and all of the units it drives. With the larger ac gate supply voltage, the total drop in the winding resistance and rectifier γ_1 will still leave an output voltage E_o larger than any of the reset voltages that might appear in

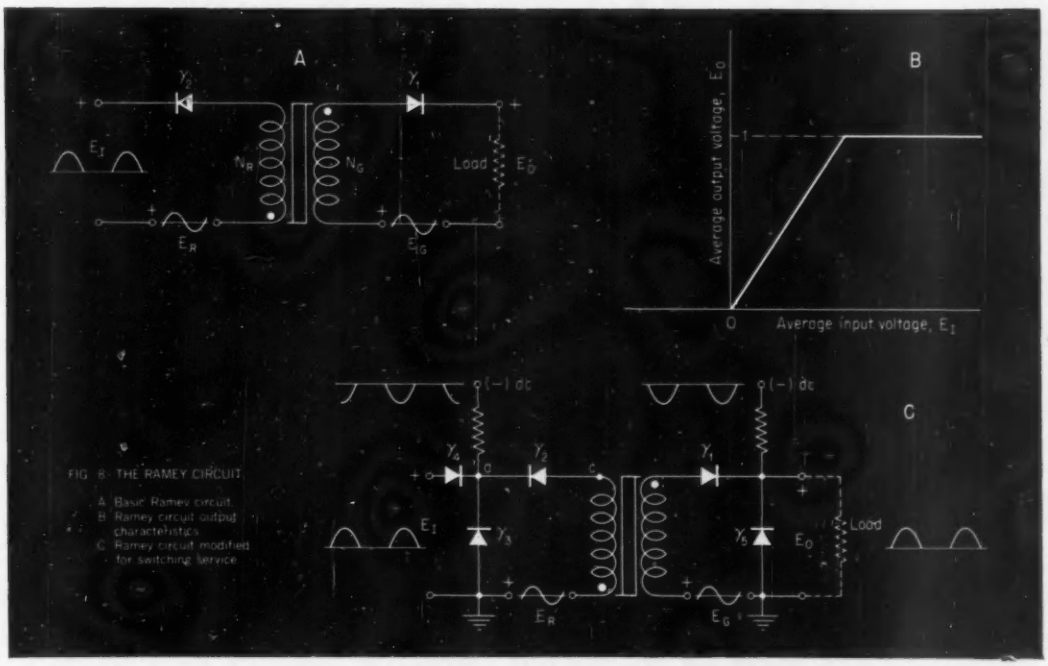
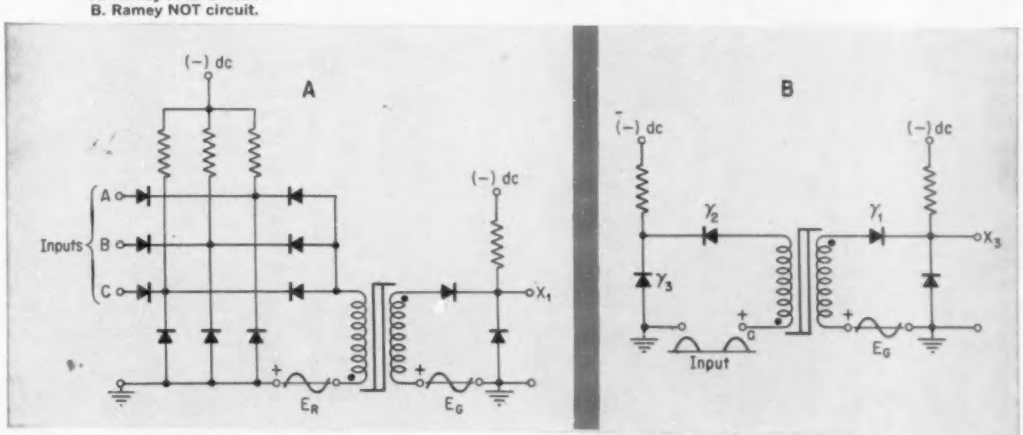


FIG. 8. THE RAMEY CIRCUIT.
A. Basic Ramey circuit.
B. Ramey circuit output characteristics.
C. Ramey circuit modified for switching service.

FIG. 9. LOGIC-UNIT CIRCUITS DERIVED FROM BASIC RAMEY CIRCUIT.
A. Ramey AND circuit.
B. Ramey NOT circuit.



the driven units when a number of units are being driven. It should be noted that the inputs to these units do not necessarily have to be the half-wave sinusoidal voltages shown. A full-wave rectified sinusoidal voltage could be used, or even a dc voltage as long as it is large enough to prevent reset.

Figure 9A shows an AND circuit evolved from the modified Ramey circuit of Figure 8C. This circuit has three inputs, each similar to the single input in Figure 8C. As long as any one of the inputs *A*, *B*, or *C* is not present, there is a reset path for the magnetizing current through the rectifier corresponding to that particular input. There is an output only when all inputs are present simultaneously, since in this case there is no reset path.

The modified Ramey configuration can be easily converted to a NOT circuit. If only the input signal with polarity as shown in Figure 9B is introduced in the reset circuit, and not the usual reset ac supply voltage, then the circuit resets (or yields no output) only when the input signal is present. This is the NOT or negation function in logic. However, if the input signal is not present, there is no reset voltage to drive the flux down during the reset half-cycle and no reset occurs. With no reset from positive saturation, an output appears for the full gating half-cycle.

This circuit also requires the γ_3 rectifier, which here has the important function of limiting the current flow when an input is present at terminal a in Figure 9B. This input drives the flux downward until on reaching negative saturation the voltage no longer appears across the winding. The winding then presents a low impedance, so that under normal circumstances a large current would tend to flow. However, being limited by rectifier γ_3, this current can only increase to slightly over the magnetizing current. The bias current through γ_3 from the minus dc supply permits the winding current to increase only until rectification limits additional negative flow.

Conventional magnetic amplifiers as switching devices

The usual magnetic-amplifier circuits, such as center-tap, doubler, full-wave bridge, etc., can be adapted for switching service[7]. Figure 10A shows the magnetic-amplifier output characteristic as a function of input ampere-turns. Notice that for negative signals the output characteristic is zero until nearly zero input ampere-turns. As the ampere-turns applied to the magnetic amplifier are increased from extreme negative values toward zero, the usual analog or proportional control region is reached. In this region, the output voltage increases approximately linearly with net input ampere-turns. But when the output or gating winding on the magnetic amplifier has no voltage drop (low "impedance" presented at winding) during the gating half cycle, and the load current flows for the full gating period, the output average voltage stops increasing just short of zero ampere-turns. Thus, the conventional magnetic amplifier has the makings of a digital device—the output is either ON or OFF except for the comparatively small linear region.

With the proper bias and signal magnitudes and the proper polarities, many logic functions can be performed with a single magnetic amplifier unit. For example, Figure 10A shows the magnetic amplifier characteristic when the bias and signals are arranged to give an AND function, X_1 of Table II. The bias is minus three units of ampere-turns, and each of the signals *A*, *B*, and *C* are applied in a positive ampere-turn sense. Note that when two or less of the three input signals are present, the amplifier output is OFF. However, when all three of the signals *A* and *B* and *C* are present the amplifier is ON.

By decreasing the bias magnitude, different functions can be performed. Figure 10B is illustrative; it shows the bias as minus one ampere-turn unit, with the three input signals unchanged from part A of the figure. Now it is seen that for any one of *A* or *B* or *C*, there is an output voltage from this magnetic-amplifier unit. This then is an OR performing magnetic amplifier.

If the bias is eliminated entirely and only signal *A* is used in a negative sense, the magnetic amplifier will not have an output when A is present, Figure 10C. This is a means of generating the NOT function of A, X_8 of Table II.

To gain more insight into the possibilities of using magnetic amplifiers as switching devices, consider what can occur between the situations of Figures 10A and 10B. This is intermediate to the AND and the OR function in the sense that the bias is between the values of minus three for the AND function and minus one for the OR function. With a bias of minus two units, the unit is OFF for one or less signals, and ON for two or more signals. This can be expressed by the switching algebra function that gives the three possible combinations of two signals at a time:

$$AB + BC + CA \tag{17}$$

The preceding examples show that a magnetic-amplifier unit responds to the algebraic sum of signals, and thus can easily be designed to give an output for many combinations of bias and multiple signals. Yet these signals need not each be positive. A magnetic amplifier of this type can respond to two or more signals of the nature of (NOT A), (NOT *B*), and (*C*). This is the switching function of X_8 in Table II if the first and third "don't care" condition are used as 1's. It gives the logic function

$$\bar{A}\bar{B} + \bar{B}C + C\bar{A} \tag{18}$$

Figure 10D shows the output characteristic for this function. No bias is used and signals *A* and *B* are shown in the negative sense. This is because the function is two or more of $\bar{A}$ AND $\bar{B}$ AND *C*. Thus, the negative portions of the logic function are applied to the magnetic amplifier in the negative sense.

It can be noted in checking Table II that an output occurs only for the four cases given for X_8 (where two of the cases are those listed in the table and the other two result from considering the first and third "don't care" conditions as 1's). For example, if signal A is present the operating point is minus one ampere-turn units, while if *C* is present also, the operating characteristic is brought back to zero net ampere-turns, or to an output condition. This shows in a more subtle way how this unit can give an output for two or more of the input signals. In addition,

FIG. 10. SWITCHING SERVICE CHARACTERISTICS OF CONVENTIONAL MAGNETIC AMPLIFIERS.

A. Magnetic amplifier characteristics with bias and signals for AND function.
B. Characteristic for OR function.
C. Characteristic for NOT function.
D. Combined switching function.
E. Combined switching function.

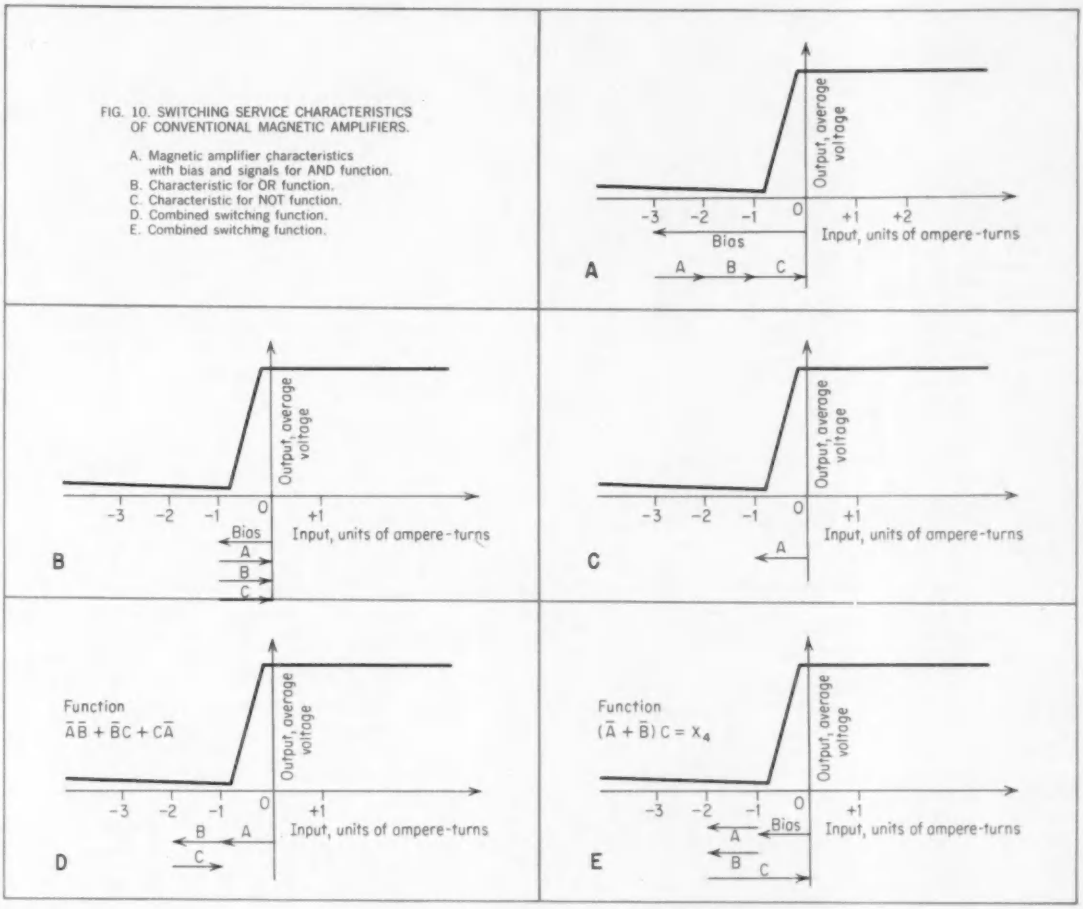
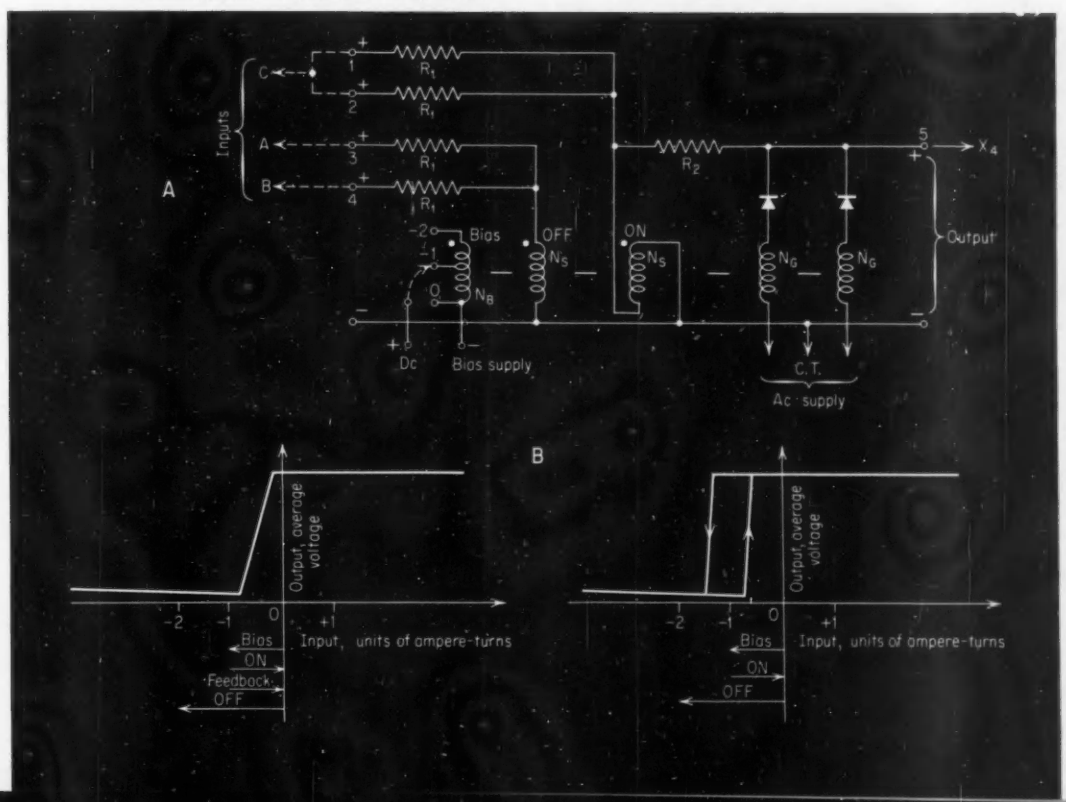


FIG. 11. CENTER-TAP MAGNETIC-AMPLIFIER CIRCUIT CONNECTED FOR SWITCHING SERVICE.

A. Connected for function X_4 of Table II.
B. Memory characteristic of center-tap circuit.



without separate units, this magnetic amplifier can perform the NOT operation for any individual signal by using the sense of the required signal.

In the logic functions considered in Figures 10A, B, C, and D, each signal has the same amplitude. This means that no one signal predominates over the others, even though many logic functions have one or more of the signals entering into the logic in a predominate manner. Function X_4 of Table II is an example. This switching function is C and ($\overline{A}$ or $\overline{B}$), so that C enters the logic in a predominate or unsymmetrical manner compared to $\overline{A}$ and $\overline{B}$. This indicates that C should probably have a signal magnitude different from $\overline{A}$ or $\overline{B}$, and that $\overline{A}$ and $\overline{B}$ should probably have equal signal magnitudes since they enter the logic in a similar manner. Figure 10E shows how to implement this logic function. The bias and signals $\overline{A}$ and $\overline{B}$ each have a magnitude of minus-one units. But C has a magnitude of plus-two

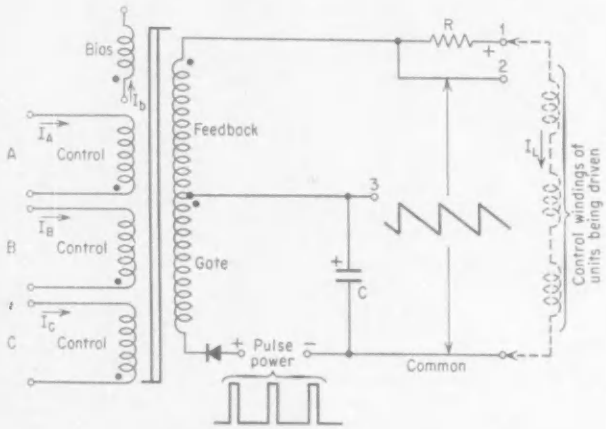


FIG. 12. Basic circuit of pulsed magnetic amplifier for switching service.

units. Thus there is an output whenever C is present except when signals A and B are both present.

Table II can be modified to show exactly when an output is or is not present for given input signal magnitudes and polarities. This is done by inserting the magnitude and sign of the signal in Table II instead of the 1's, whenever that particular signal is present. In this case it would mean that A would have a magnitude of minus one whenever its signal was present, and B would have a magnitude of minus one whenever its signal was present. C, though, would have a magnitude of plus two when its signal was present. The sum of the A, B, and C signals plus the bias magnitude of minus one for each of the eight input combinations, determines the net input signal. If this sum is minus one or less, the amplifier is in the OFF state; if it is zero or greater, the amplifier is in the ON state. Doing this for the logic function of Figure 10E shows that there are net inputs of zero or greater only for the three cases in Table II when an output is present for X_4.

A large class of combinational logic functions can be handled by individual magnetic amplifiers on the basis just discussed. It is advisable to tabulate the required signal magnitudes and polarities along with the bias magnitude and polarity for each of the possible logic functions. This cataloging could be quite extensive, particularly if the much-used combinations of multi-purpose units are included, but it will save engineering time on most specific design problems.

Note that if the bias used in Figure 10E is reduced to zero, the form of the logic function is altered such that the AND and OR operations are now reversed. Thus the switching function when no bias is present is ($\overline{A}$ and $\overline{B}$) or C. Switching algebra notation gives

$$\overline{A}\overline{B} + C \qquad (19)$$

The appearance of the switching function is not changed much from that of the figure, since C enters as a positive signal and (A and B) are still NOT functions. Thus, by changing just the bias and not the signals, the switching function is altered even though C, the larger of the two signals, is twice the size of the negative signals A and B.

Figure 11A shows a center-tapped magnetic-amplifier switching circuit, with two magnetic cores of sharply saturable material. Each core has a gating winding on it of N_g turns. The ON and OFF signal windings of N_s turns are wound to include both magnetic cores. All input signals are positive, and the sense of the ampere-turn polarity for the OFF winding is opposite to that of the ON winding. Positive input signals applied to terminals 1 and 2 give ampere-turns that tend to turn on the magnetic-amplifier output, while positive signals applied at terminals 3 and 4 tend to turn it off.

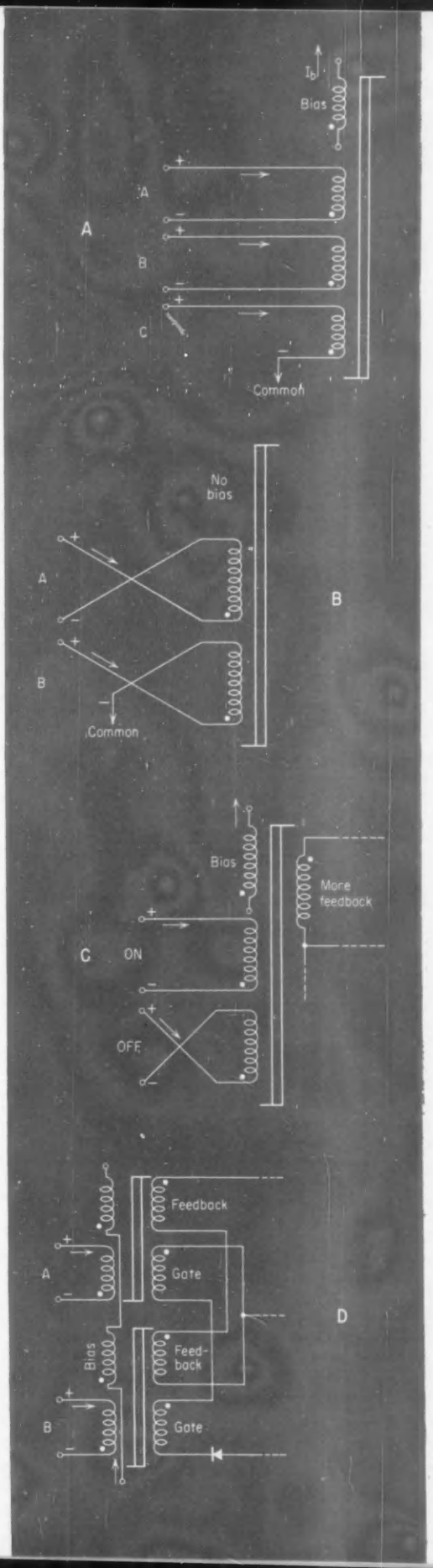
To produce the logic function of Figure 10E, the dotted connections of Figure 11A must be added. Signals A and B both appear in a NOT or negative sense, so they are applied to terminals 3 and 4 of the OFF winding input. The two units of positive amplitude then for signal C are furnished by connecting terminals 1 and 2 together and applying signal C to the junction. Mixing resistors R_i are paralleled when terminals 1 and 2 are connected, so that about twice the current flows for C that flows for either signal A or B. Mixing the signals through resistors at each input is possible if R_i is large compared to the winding resistance of N_s turns. The bias required for Figure 10E is minus-one unit. This is accomplished in the center-tap circuit by making the dotted connection shown for the bias winding. This uses one-half of the possible bias turns.

Resistance R_s provides a small amount of positive feedback, so that as the input signals start to turn ON the magnetic amplifier, they are aided by the current flowing through this resistor to the ON winding. Thus the amplifier turns on more rapidly than is possible without feedback. This causes the output characteristic of Figure 10A to become steeper and to "snap" in changing state.

Additional positive feedback on this type of switching magnetic-amplifier circuit will give it a memory or storage characteristic. Sufficient positive feedback will make sure that the amplifier drives completely ON once it starts to turn ON. This can be accomplished in Figure 11A by connecting the output terminal to terminal 1 of the ON winding circuit,

FIG. 13. CONTROL AND BIAS WINDING CONNECTIONS FOR PULSED MAGNETIC-AMPLIFIER LOGIC CIRCUIT.

A. OR unit connections.
B. NOT or NOR unit connections.
C. Memory unit connections.
D. AND unit construction.



and applying the external ON signal to terminal 2. As shown in Figure 11B, once the amplifier is turned ON, the feedback will hold the amplifier ON even after the external ON signal goes to zero. Thus, the ON signal has no further control over the circuit until it can be turned OFF by some means. One way is to apply an OFF signal at terminals 3 and 4 connected together. The result is an OFF signal double the magnitude of either the ON or the feedback signal. Then the OFF signal can turn the amplifier OFF even if the ON signal is still present.

The right-hand portion of Figure 11B shows the bistable characteristic that results if the positive feedback is considered as a part of the characteristic and not as an external signal. Note that an ON signal turns the amplifier ON, but that even after the ON signal goes to zero the amplifier will not turn OFF because the path to be followed by a decrease in output is to the left of the path for an increase in output. However, even if the ON signal is present, the double-magnitude OFF is still sufficient to turn the amplifier OFF. This shows how feedback is used for memory, though this feedback is somewhat different than the feedback present when logic units of OR-NOT feed another OR-NOT, which in turn cross-feeds the first, Figure 6C.

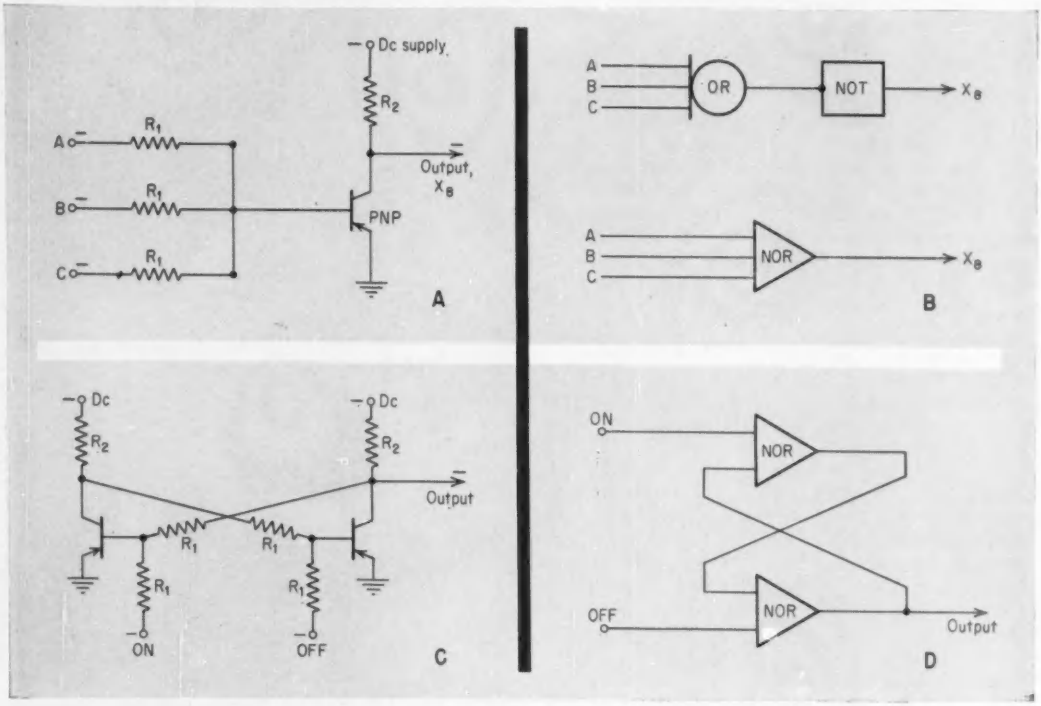
In summary, magnetic amplifiers, or for that matter any type of amplifier that has two definite output states that respond to the sum of input signals, can be used as switching or logic devices. And since a number of input signals can be mixed, a considerable number of combinations of switching functions may be possible.

This feature is useful not only for units specifically designed for logic service, but also for output-power magnetic amplifiers. In fact, it has been found in a number of cases where the logic to be performed is relatively simple, that the entire logic can be performed by using mixing resistors and/or several separate signal windings fed from these resistors. Thus, simple logic can be performed on the control windings of the power output amplifier, which would normally be required anyway.

Switching systems sometimes require time-delay elements to make sure that operations occur in the proper sequence. Time delays of several seconds can be obtained in either type of magnetic-amplifier switching circuit by charging or discharging capacitors through resistors or nonlinear elements such as rectifiers that control charging rate. This may be a time delay in turning ON or turning OFF the amplifier after the motivating signal has been applied.

An entirely different method of time delay is possible by using a very low impedance control-winding circuit. For example, if in Figure 11A the resistors R_1 at terminals 3 and 4 were removed and the OFF winding either shorted or closed through a low resistance, there would be a delay between the application of an ON signal and the turning ON of the amplifier. This delay is caused by the fact that the ON winding is magnetically coupled to the OFF winding and induces a voltage in it. With a low-

FIG. 14. THE TRANSISTOR NOR CIRCUIT.
A. Basic NOR Circuit.
B. Symbolic representations of NOR.
C. Basic transistor memory circuit.
D. NOR representation of memory.



resistance path, a large current will flow in the OFF winding in a direction opposing the ampere-turns that are trying to turn the magnetic amplifier ON. Thus, the net flux linkages in the circuit change only slightly each cycle of the supply voltage, and many cycles are required to turn ON the amplifier.

Pulse-type magnetic amplifier switching circuits

Another static switching system being used is also based on magnetic-amplifier-type circuits. This was developed particularly for logic devices. One of its unique features is that its gate power is supplied in the form of repetitive pulses. The pulse power supply used for a system composed of these units uses static devices to shape the pulses, primarily by means of two sharply saturable magnetic elements.

Figure 12 shows the basic circuit. The magnetic amplifier has only one sharply saturable magnetic core; the rectifier in the gate winding permits current to flow in only one direction; the applied pulse power consists of two equally-spaced positive polarity pulses for each cycle of the ac input to the pulse-supply shaping circuits; and the capacitor in the gating circuit stores energy from the pulses and discharges it through the feedback winding and load during the ON mode of operation (when the magnetic core material is near positive saturation at the beginning of a pulse). The pulse charges the capacitor almost immediately, since the core is at positive saturation and the gate winding voltage is practically zero. After the pulse, the capacitor discharges through the feedback winding and the output decreases almost linearly, giving the sawtooth shape output voltage waveform shown in the figure.

Feedback in this case causes the same change in output characteristic as it did for the center-tap circuit of Figure 11. Thus the output characteristic for the pulsed magnetic amplifier with feedback assumes the hysteresis or "lag" curve shown in the right-hand part of Figure 11B.

The rectifier in the gate winding prevents the capacitor from discharging and forces all of the discharge through the feedback winding. The resistance R in the output circuit is large compared to any possible connected load (the usual load is the control windings of similar-type devices being driven by this one). The total resistance of these control windings in series is usually fairly small compared to R, so that the required average current can flow through the driven windings during the ON condition.

If the amount of feedback is small, and a negative bias is used to make sure that the unit is OFF when none of the inputs A, B, or C is present, the presence of any one of the input signals will provide sufficient ampere-turns to switch the unit ON. Terminals 2 and 3 are provided to give greater flexibility. For example, if more than ten control windings in series are being driven by this unit, the average output current when the unit is ON will be somewhat less than the desired value. In this rare case, another resistor is placed between terminals 1 and 2, shunting resistor R and bringing the load current back to the proper level. Resistors connected between terminals 1 and 3 can decrease the amount of feedback and thus alter the output characteristic to meet special requirements.

One advantage of a pulse-driven circuit is that it

can saturate at a small value of integrated volt-seconds. This means less core material and fewer turns, and thus a unit that is smaller and cheaper than one designed to be supplied by a larger value of volt-seconds each cycle. Another advantage is that the pulse voltage can be high enough so that in the event of a poor or corroded connection, sufficient voltage is available to break down the resistance.

When the bias or control signals produce negative ampere-turns so that the unit is OFF, the output voltage does not go completely to zero. It is one reason why this circuit uses only a single signal to turn it ON or OFF. This means that the bias used with this circuit can only be minus-one ampere-turn units or zero, and that even though the amplifier uses additive ampere-turns to determine the output state, the circuit of Figure 12 cannot be used as an AND circuit as in Figure 10A, where the three signals add to give the output.

This does not mean, however, that the input is restricted to one signal, even though the way the circuit is used, only one signal can be used to change state. It does mean, though, that unlike the two previously discussed circuits, no special method is required to quell the small zero output signal.

Figure 13 shows the control and bias winding connections for several logic units constructed from the pulsed magnetic-amplifier circuit. In 13A the bias and signal connections are for a OR logic unit. Here the bias gives one unit of negative ampere-turns and each signal one positive unit of ampere-turns. The resulting output characteristic is exactly that shown for the OR function in Figure 10B. There is an output for input *A* or *B* or *C*.

In 13B the connections are for a NOT or NOR logic function. If only input *A* is used, then the output is NOT *A*. This corresponds to Figure 10C, where a negative signal *A* gives the output characteristic of NOT *A*. This unit has two inputs, though, so it is actually a combination of two logic functions, an OR unit followed by a NOT unit. This combination is sometimes called a NOR logic function. Thus, there is an output for only neither *A* nor *B*.

The memory unit connections are shown in Figure 13C. The bias is minus-one unit, and there are two control windings of opposite polarity. Many more turns are used on the feedback winding to widen the bistable band between the ON and OFF states of the output characteristic, as shown in the right-hand portion of Figure 11B. The control winding with positive-winding sense is used for the ON signal, and the one with negative sense for the OFF signal. Figure 11B shows that when neither the ON nor the OFF signal is present, the output state corresponds to that of the last signal present.

The AND logic unit operates on the same basic principle as the other units. But here, the ampere-turns as such are not added; rather the flux produced by them is added. Important use is made of the fact that the relationship between ampere-turns and flux is nonlinear for saturating magnetic circuits.

The OR, NOT, and memory logic units of the pulsed magnetic-amplifier type required only one signal to turn the unit ON or OFF. However, a two-input AND unit requires two signals to give an output. For this reason the construction of the magnetic circuit for the AND unit is decidedly different than that of the other units. The AND logic unit magnetic circuit has as many separate magnetic cores or apertures in a single core as there are inputs. Figure 13D shows this for a two-input AND unit with input signals *A* and *B*. The effect of the separate magnetic path for each signal is digital in nature. Thus, if signal *A* is large enough its magnetic path will saturate. However, until signal *B* is also large enough to saturate its magnetic path there will be insufficient flux to give an ON output, since the usual gate, feedback, and bias windings include both of the separate magnetic paths. In fact, either signal can be many times that value required to saturate its magnetic path and the unit will still not turn ON since the main voltage drops appear across the gate and feedback windings because of the unsaturated magnetic path associated with the other signal. The bias is negative and of sufficient magnitude to require that for normal ON input signals at either *A* or *B*, the corresponding magnetic circuit flux is forced to positive saturation. This magnetic summing limits or clips each input signal. Four or more inputs can easily be summed to give an output only when all of the inputs are present[8].

Transistor switching circuits

Of the other static logic devices, transistors, perhaps in conjunction with magnetic elements, appear to offer one of the shining hopes for the future, with their lower power consumption, small size, and excellent performance as a switch. Though manufacturing problems (resulting in questionable reliability) have limited the application of transistors to industrial static switching service, these problems are being gradually overcome, and the transistor will undoubtedly play an important future role in this field.

Just as there are many ways to use magnetic devices in switching service, so there are many possible transistor circuits. A basic transistor logic circuit is shown in Figure 14A. This circuit is simple and makes good use of the transistor as a switch[9]. The logic function it performs is sometimes known as the NOR function, which is actually a combination of an OR followed by a NOT, as shown in Figure 14B. (Note that the same symbol is used to represent both the NOR and amplifying functions.) The OR function is achieved by the resistive mixing of the input signals *A*, *B* and *C* through resistors R_i, connected to the base of the transistor. If a negative signal is applied to one or more of the inputs, the transistor becomes a good conductor and thus practically a closed switch. In this case the output is zero, since it is essentially tied to ground. If none of the input signals *A*, *B*, and *C* is present, there is an output X_o. Table II shows the input combination.

This output can be used to drive the inputs of other NOR units, and complete logic systems can be built up. The interesting point is that NOR units can perform the functions of AND, OR, NOT, and memory logic units. In fact, NOR elements used as standard logic building blocks can replace entire systems of primitive logic functions.

A memory or flip-flop circuit can be constructed out of two NOR units. The basic memory circuit

shown in Figure 14C uses two two-input NOR units. If an ON signal is present, the base of the left-hand transistor is made negative and the left-hand transistor conducts. Connecting the left-hand transistor collector through resistor R_1 to the base of the right-hand transistor, makes sure that the right-hand transistor will not conduct by applying zero voltage to its base. Thus there is an output which remains even after the ON signal is removed. As soon as an OFF signal is applied, the output goes essentially to zero and remains that way until another ON signal is applied. Functionally, this performs the same as the logic circuit of Figure 6C. In practice, the memory circuit and basic NOR circuit usually have additional resistors and rectifiers.

Transistors can be almost one-to-one replacements for single-contact relays[10]. If a signal is applied to the base contact of a transistor in a circuit such as the one shown in Figure 14A, the transistor conducts like a closed switch and acts much like a normally-open relay. An OR circuit thus can be constructed from a parallel arrangement of transistors, and an AND circuit from a series arrangement.

Other static switching devices

Several other kinds of static switching devices have been developed and used in digital computers or data-handling systems of one kind or another.

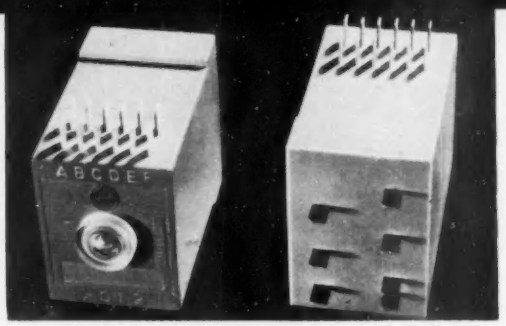


FIG. 15. Front and rear views of General Electric ICD static-switching units.

One is ferro-resonant circuits which are bistable and thus act as binary elements. Circuits consisting of ferro-resonant trigger pairs and like elements have also been contemplated.

Magnetic cores have been used as memory devices in large-scale data-handling systems, where the one of two possible saturated states indicates the information content. By special investigational circuits these memories can be interrogated to check the state of particular rectangular-loop cores. These devices can be made quite small.

Other magnetic-type static switching devices come under the classification of multi-aperture cores. These can be used for signal modulation, or in memory systems where the state of the flux level in a core is remembered as in a conventional magnetic amplifier. Special semiconductor devices also show promise as static switching units. One such element is the double-base diode[11].

A LOOK AT COMMERCIALLY-AVAILABLE SYSTEMS

At the present time only Westinghouse Electric Corp. and General Electric Co. are actively producing static switching devices and systems for industrial control service. However, the Boston Div. of Minneapolis-Honeywell has indicated that it will soon enter the field, and other manufacturers of standard relay and motor-starting control equipment may follow suit. Thus far, the magnetic-amplifier-type circuits discussed form the prime basis for the logic devices in existing commercial systems.

Westinghouse Cypak systems

Westinghouse was the first in the field with the Cypak units, which have been available for about two years. As is common with new developments, these units were originally supplied in an open-wired form; they have since been packaged in neat, handy encapsulated modules.

The elements are based primarily on the Ramey circuit. The Cypak AND unit uses a circuit of the type shown in Figure 9A, and is available in one-input, two-input, and three-input models. Each can be provided with additional inputs from special separate modules, each containing the extra rectifiers and resistors required for the additional AND inputs.

The Cypak NOT circuit is shown in Figure 9B. This unit is available in a module that also contains a two-input OR circuit. Together they form a half-memory element, since they can be combined with another half-memory module to form a memory unit of the type shown in Figure 6C.

The Cypak OR circuit is of the type shown in Figure 7B. A number of the Cypak logic modules (for example, the half-memory unit mentioned previously) contain a two-input OR circuit, and one contains two of those two-input OR circuits.

Another logic module available in the Cypak series contains a retentive memory addition element. This element, along with two half-memory units, gives what is known as a permanent memory. The retentive element "remembers" the state of a memory just prior to a loss of power, and makes sure that when the power is reapplied the memory is in the state held just before power failure. In effect, it stores this information as the saturation level in another sharply saturable magnetic core.

Another Cypak module can give time delays of up to 20 sec, and even longer with added elements.

All of the Cypak logic elements are packaged in molded plastic blocks of the polyester series. All power connections are on one face of the block, and all logic connections are on the other face. The power connections plug into special power terminal strips. The logic connections are made primarily between one logic element and another, using the terminals on the top surfaces. The busbar power channel is designed so that phase of the power supplied to the logic elements depends on the orientation of the power unit when it is plugged in. The phase can be reversed by removing a unit, rotating it 180 deg, and plugging it in again.

A unit containing two separate initial-input transformers is also available in module form. These are used with the original circuit inputs (pushbuttons or limit switches), and operate on 110 vac. The input transformers step down this voltage to approximately 16 volts. It is then rectified to give a full-

wave output and used as the input signals to the Cypak logic elements.

The output elements designed for Cypak units include preamplifiers and output power amplifiers in ratings of 50, 150, and 300 volt-amperes steady state. Regulation specifications on the amplifiers indicate inrush characteristics.

GE Industry Control Dept. systems

Within recent months General Electric Co. announced the availability of two different static switching systems. The ones produced by the Industry Control Dept. (manufactured in Roanoke, Va., and identified hereafter as ICD devices and systems) are based on a center-tap magnetic-amplifier circuit of the type shown in Figure 11[12]. They are designed on the multi-function principle to reduce the number of units required in a complex system and to increase the flexibility of the individual units.

A red unit (colored for identification purposes) uses essentially the circuit of Figure 11A, but with three OFF signal inputs. There is also a monitor light across the output to indicate when the unit is ON. This aids in maintenance and gives an indication of switching-sequence progress during operation. The monitor light uses a 12-volt filament-type bulb operated at about half-voltage (unit output is about 6 volts) for long life. This unit, and other similar units in the series, have provisions for holding the output signal level in the OFF state to a very low level, as do the Westinghouse Cypak units.

A blue unit in the ICD series is similar to the red unit except that it has three ON inputs and two OFF inputs. A black unit has one ON signal winding only, but with the various inputs and resistor combinations provided, time delays of up to 10 sec can be achieved in turning ON or turning OFF the unit by connecting an external capacitor. A green unit provides short time delays by magnetic action. Brown and yellow units are OR and AND logic elements of the rectifier type shown in Figure 7A.

A gray switching unit contains an NPN silicon transistor used as an isolation switch. The transistor acts like a controlled switch in series with either a silicon or a germanium-junction rectifier. The silicon rectifier terminal connection is used if the leakage current must be kept extremely low, the germanium rectifier terminal if an extremely low forward drop is required. A purple unit, also available, has three isolated windings and no internal feedback. This unit is used when inputs are at different voltage levels and cannot be tied to a common input.

The gray unit is used primarily in regulator circuits where it is necessary to open or close the circuits without introducing false voltage signals. Unlike the other switching units, it has the function of actually switching from a high impedance to a low impedance in a circuit, rather than giving or not giving an output voltage for the ON and OFF states.

Figure 15 shows the front and rear views of two ICD static switching units. In the unit on the left, the monitor light is in the middle of the front face. The terminals on the top are for signal input and output, and those on the bottom are for bias. The right-hand unit shows the seven power-input terminals that plug into the common power bus.

Memory is obtained from these static switching devices by applying positive feedback to the ON winding. In a temporary-type memory, the system assumes the OFF output state when power is restored. This is accomplished by the special power supply used with static switching systems, which applies the bias a fraction of a second before the ac power. In a permanent memory, all units return to the same state they were in prior to the power failure. This is accomplished in the ICD system by an additional sequencing system in the power supply. No additional logic units are required, but the supply must be modified to follow this sequence on restoration: first, power is applied to the constant voltage transformer; then, one cycle later, it is applied to the bias circuit and ac power is applied at a reduced value; and finally, two cycles after the reapplication of power, full ac voltage is applied.

GE General-Purpose Control Dept. systems

The other GE static system is being produced by the General Purpose Control Dept. (manufactured in Bloomington, Ill., and identified hereafter as GPCD devices and systems) and uses the pulse-gate-power type circuits previously discussed[13]. Figures 12 and 13 show the basic circuit for this type of half-cycle-response magnetic amplifier, and the particular connections required to form various logic units. These pulse-power-supply units have a half-cycle response to an input signal, as does the Ramey circuit. The center-tap magnetic-amplifier circuit in the ICD systems does not have this half-cycle response.

The logic elements that make up the GPCD series reflect the considerable effort expended to make these units fairly inexpensive to manufacture and moderately easy to apply. For example, the electrical connections (all plug-in-type connectors) are located in the molded base at the bottom (Figure 16 shows seven different GPCD units). Note that the center portion of the molded base is raised so that it can orientate the elements in the base receptacle. The metal strip on each unit can hold a neon lamp, which lights when the unit is in the ON state.

Another feature of the elements in Figure 16 is

FIG. 16. Seven different types of GE GPCD static-control elements.

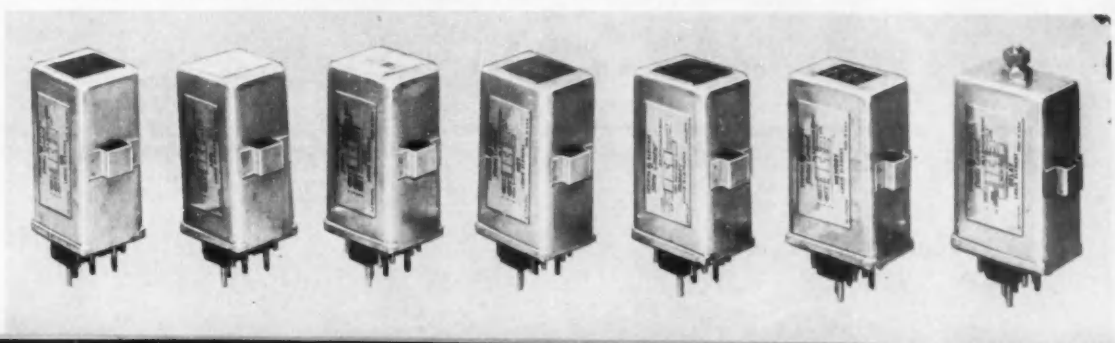


FIG. 17. Westinghouse Universal Switching Amplifier with component mounting header.

that the bias connections are all made in series. The pulse power supply is designed so that if the bias circuit opens at any point in the system, the supply pulses cease. Thus, for this type of failure, the system fails safely.

Also available in this system are a release memory and a permanent memory. The release (or temporary) memory always reverts to the OFF output condition in the event of power failure and subsequent power return. When the power is turned on a relay opens the pulse supply circuit momentarily so that the bias power is always applied first. This makes sure that the element is driven to the OFF output condition. The permanent memory, on the other hand, uses no external sequencing when the power is turned on. The bias and pulse supply are in series and are designed to come on at the same time since the time constants for both circuits are about equal. The core condition is retained on power removal, since the time constant of the bias circuit is about the same as the *CR* time of the output element.

The time-delay element is magnetic. It is shown as the right-hand unit in Figure 16, with the adjusting terminal on top. Time-delay elements are available in three overlapping ranges, from 0.1 to 20 sec.

The magnetic cores in these elements consist of stacked laminations of grain-oriented material with universal-type wound coils. These should be somewhat cheaper to manufacture than the toroidal-wound cores of the other systems. The power level in the logic elements is again purposely kept low. The output signals of the logic elements must be amplified to a working level in specially designed power amplifiers that give "snap" OFF action and zero OFF output. Static power amplifiers, such as conventional magnetic-amplifiers, are normally used.

Westinghouse Universal Switching Amplifiers

The three static-switching systems just discussed all require special power supplies to give the proper voltage magnitudes and waveforms. To solve this problem in small-scale systems, where the cost of the power supply may be an appreciable part of the total system cost, Westinghouse developed a "Universal Switching Amplifier", which is more nearly a direct counterpart to a standard control relay with a number of contacts. That is, it can be used many ways and requires only one ac supply voltage. Also, it operates at a higher power level, so that for some applications the load can be driven directly.

Figure 17 shows this Westinghouse amplifier. The lower part contains a magnetic amplifier with four separate control windings and a tapped bias winding. These and the load windings are brought out to the terminals on the "can". The upper molded header holds the rectifiers and resistors.

This unit is another example of a multi-purpose magnetic-amplifier logic element that can perform any of a considerable number of combinational logic functions to give the designer extreme freedom in applying each unit within a specific system. The price of this flexibility is paid in increased system-engineering-design time, although this effort may, in many instances, result in a logic system that requires fewer components than any of the other systems.

When these units drive power-output amplifiers no preamplification is necessary. Frequently the required logic operations can be performed partly with a few Universal Switching Amplifiers, and the remainder with mixing resistors and the control windings of the power-output magnetic amplifier.

STATIC-SWITCHING SYSTEMS APPLIED

Since the introduction of static logic devices for industry two years ago, there has been a variety of applications in different industries. Machine-tool builders have been one of the largest users, due to the demands of the mass-production industries for more operations in a shorter period of time with less maintenance. But no industry can completely overlook these devices. The applications in the following sections are limited to specific interesting portions of the circuit, since the complete circuits are too complex for detailed coverage.

To a dual-ram broaching machine

Figure 18 shows a dual-ram broaching machine built by the Colonial Broach Co. for the Ford Motor Co. and controlled by a Westinghouse Cypak system. The machine operates as follows: While one ram is machining the workpiece on its platen, the operator replaces the previously machined workpiece on the other platen with a new piece. Limit switches indicate the up-and-down movement of the rams and the in-and-out movement of the platens, both of which are hydraulically positioned. The hydraulic system is controlled by eight solenoid valves operated by the static-logic system. The machine can be operated in any one of three modes: single-cycle, jog-cycle, or continuous-cycle. The continuous or automatic cycle is described here since it makes the fullest use of the logic system.

Figure 19 is a schematic diagram, simplified to show only the automatic cycle of operation. Many of the safety features, as well as the control of the right- and left-hand ram prefill solenoid valves and the vent

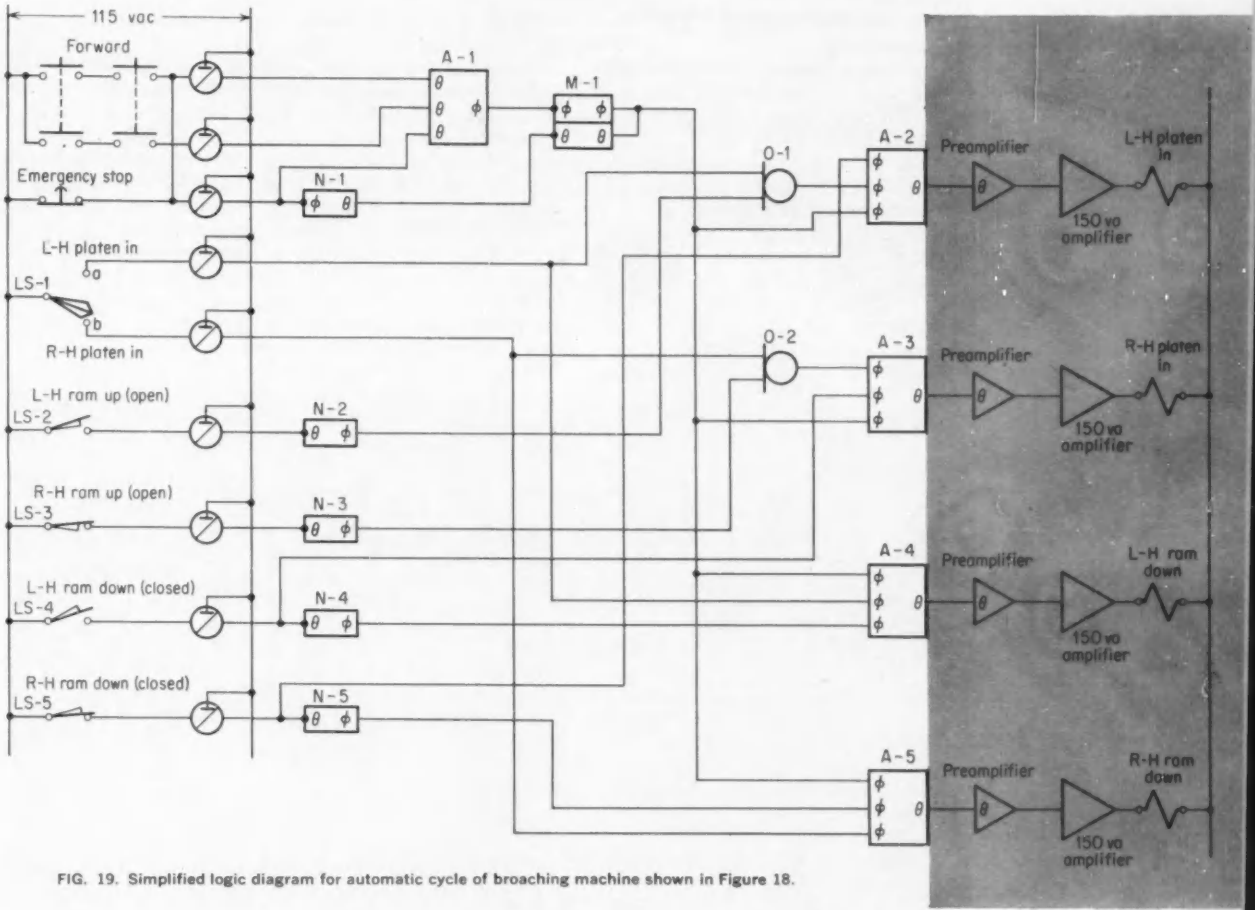


FIG. 19. Simplified logic diagram for automatic cycle of broaching machine shown in Figure 18.

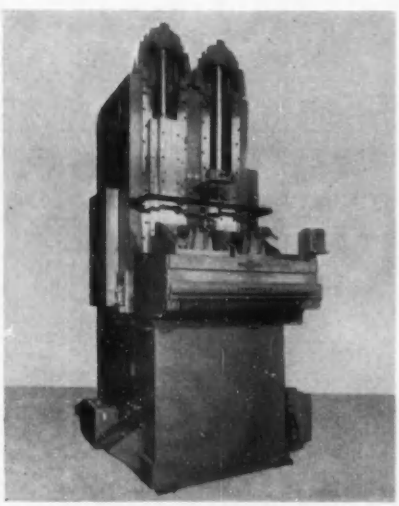


FIG. 18. Dual-ram vertical broaching machine built by Colonial Broach Co. for Ford Motor Co. and controlled by a Westinghouse Cypak system.

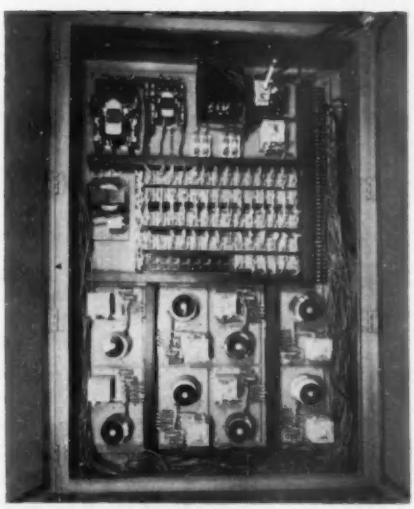


FIG. 20. Cypak control panel for dual-ram broach of Figure 18. Note the front connections on the Cypak modules for the signal inputs and outputs. Power connections are all made when unit is plugged into power bus.

and transfer valves, have been omitted. Thus the figure is a skeleton of the logic system.

The cycle is initiated by pressing both forward pushbuttons, which gives an output from the A-1 AND unit, and in turn turns ON memory M-1. The memory output signal is applied to one of the inputs of all four AND units, A-2, A-3, A-4, and A-5. At this point it is possible to follow the sequence of events for one complete cycle of operation.

Assume that the initial state of the system is indicated by the position of the limit switches *LS*-1 through *LS*-5, which in turn indicates the ram and platen positions. *LS*-1 shows that the right-hand platen is in machining position. It can also be seen that the left-hand ram is up and the right-hand ram down. In this position of the broach, there is an output signal from NOT unit N-2 applied to the input of OR unit O-1. This provides a second input to the three-input AND unit A-2; the third input comes from the output of limit switch *LS*-5, closed when the right-hand ram is down. With all three inputs present, A-2 turns ON, and its output is amplified to energize the left-hand platen-in solenoid valve. The left-hand platen moves into machining position, and as it does so it causes *LS*-1 to go to position a. This provides the third input to AND unit A-4 to turn it ON. A-4 already had ON output signals from NOT unit N-4 and memory unit M-1.

The amplified output of A-4 energizes the hydraulic solenoid valve which drives the left-hand ram down. As the left-hand ram moves downward, the right-hand ram starts to move upward, opening *LS*-5. This removes one of the inputs to A-2, deenergizing the solenoid valve that forced the left-hand platen in. Thus, the left-hand platen is in position to have its workpiece broached.

When the left-hand ram reaches the bottom of its stroke, the right-hand ram reaches the top of its stroke, causing *LS*-4 to close and *LS*-3 to open. Now all three inputs to AND unit A-3 are present. starting the right-hand platen in till it moves *LS*-1 to the b position. As the right-hand ram moves downward, the left-hand ram moves upward, opening *LS*-4 and removing one of the inputs to A-3. This deenergizes the right-hand platen-in solenoid valve. The conditions of the left- and right-hand rams (up and down respectively) complete the cycle.

Note that this sequence consists of a number of separate steps, but that there is only one memory unit shown in the circuit. Memory unit M-1 indicates an ON condition after both forward pushbuttons have been pressed, and an OFF condition only after the emergency STOP pushbutton is closed. The other required memory functions are accomplished by feedback external to the logic system. Thus, the positions of the mechanical parts in the system represent stored information required for the proper sequence of operation.

In the schematic of Figure 19, the 115 vac across the pushbuttons and limit switches feeds into units represented by a circle with a diagonal across it. These are the initial input units described for the Cypak system, and consist of stepdown transformers with full-wave rectification of the output. The input to the Cypak elements has an average value of about 15 volts. The 115 volts is used across the contacts so that any surface film or grime on the mechanical contacts will burn away.

The θ and ϕ designations on each Cypak logic unit in the schematic show the relative half-cycle of input or output. The phasing of subsequent units is important, since each unit (except for the OR unit, which does not contain a magnetic core) must be properly phased so that the core resets on one half-cycle and the output is gated on the next half-cycle.

The preamplifier units usually consist of two one-input AND units with slightly higher than normal power handling capacity. One unit follows the other so that both half-cycles of the output are amplified to drive the 150-volt-ampere magnetic amplifier, which in turn drives the solenoid valves.

Figure 20 shows the Cypak control cabinet for this system. The logic units are plugged into their power strips in the upper center of the panel, and the eight power amplifiers are in the lower portion.

To a sawmill lumber conveyor

Another Cypak application is in the control of a Lutcher & Moore Lumber Co. sawmill horizontal resaw outfeed conveyor. Here good boards must be separated from waste and nonusable boards. Figure 21 shows plan and side views of the conveyor system being controlled. Conveyor 1 is driven by a reversing gearmotor, and conveyors 2 and 3 run continuously and are not controlled by this system.

In Figure 21, two boards (one on top of the other) leave the horizontal resaw and move onto conveyor 1. The upper board is usually waste—a slab-shaped board with bark on one side. When the boards clear limit switch *LS*-1, conveyor 1 is driven to the right. The combined action of the conveyor dog and a fixed stop pulls the bottom board from beneath the upper board and drops it on conveyor 2. As conveyor 1 stops and reverses at a signal from limit switch *LS*-2, the conveyor dog carries the waste board to the left and deposits it on conveyor 3. Conveyor 1 stops and awaits the next pair of boards when limit switch *LS*-3 is operated.

If both boards coming onto the conveyor are good, the operator presses a momentary contact pushbutton marked "no-waste". This results, first, in the operations for depositing the lower board on conveyor 2, after which conveyor 1 continues to run to the right (overruns *LS*-2) for one complete revolution, passes limit switches *LS*-4 and *LS*-3, and pushes the upper board onto conveyor 2. When the conveyor dog strikes *LS*-2 for the second time it stops and reverses. When the dog hits *LS*-3, the conveyor stops and waits for the next cycle. Unless the operator again presses the "no-waste" button, the subsequent cycles will be the same as the first.

Figure 22 shows the logic schematic for this horizontal resaw outfeed conveyor. If the selector switch is in its "normal" position, and the normal initial conditions exist for all memories turned OFF and all limit switches in the position shown, the sequence can begin. One input to AND unit A-2 is provided when the boards hit limit switch *LS*-1. The other input is already present (from the normally-closed contact on *LS*-2 through OR unit O-1), so that AND unit A-2 gates an output. This turns memory

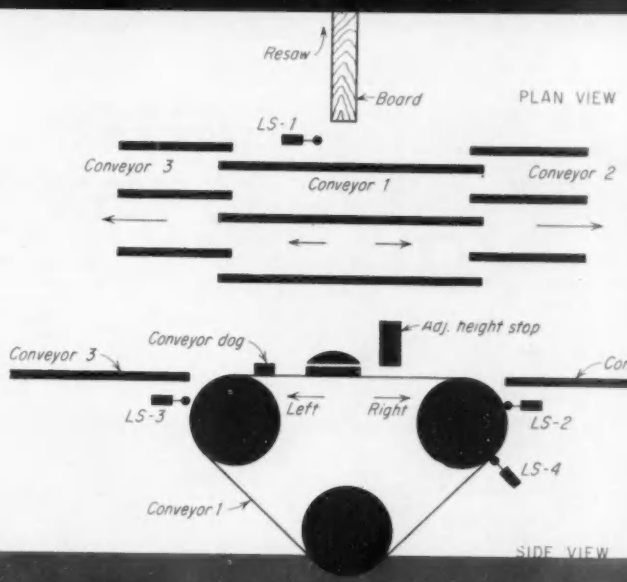


FIG. 21. Physical arrangement of horizontal resaw outfeed conveyor installed at Lutcher & Moore Lumber Co. and controlled by a Westinghouse Cypak system.

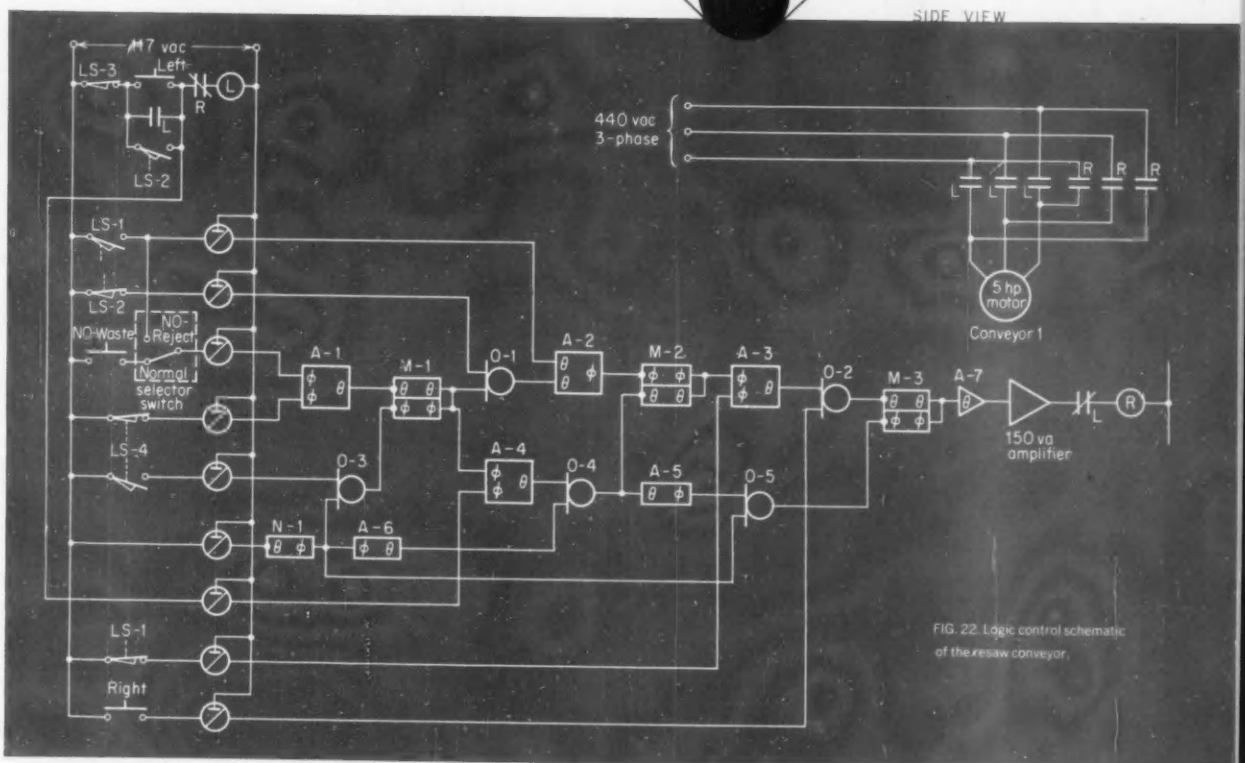


FIG. 22. Logic control schematic of the resaw conveyor.

FIG. 23. Bandsaw and resaw conveyor at the Lutcher & Moore Lumber Co.

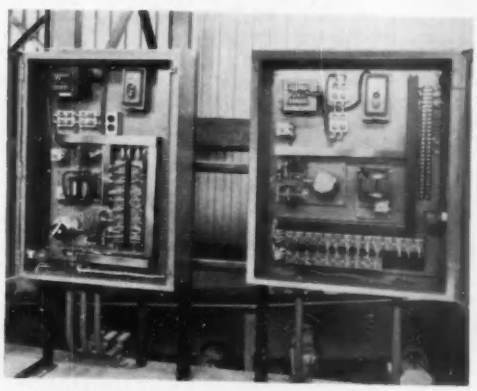


FIG. 24. Left-hand enclosure contains Cypak control units for resaw conveyor.

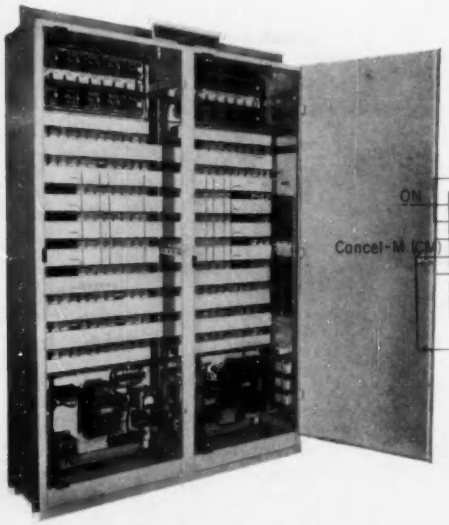
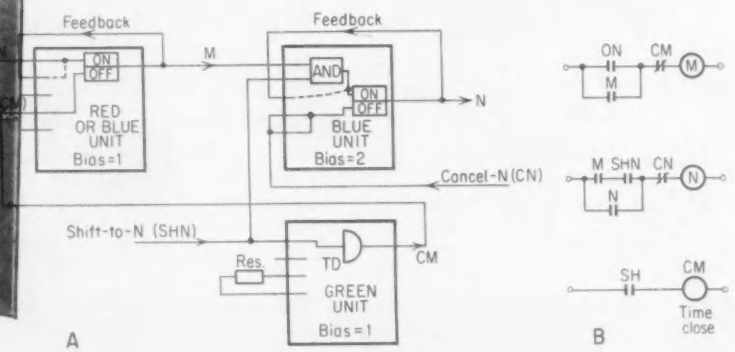


FIG. 26. GE ICD static-switching panel for control of complex conveyor system. Monitor lights on the face of the units are a trouble-shooting aid for both the control and the conveyor system.

FIG. 25. An example of shift-register logic operation as it can be performed using General Electric ICD static-switching elements.



unit *M*-2 ON, providing one input to AND unit A-3. When the boards clear *LS*-1, its normally-closed contact provides the other input to AND unit A-3, and A-3 gates an output. This turns ON memory unit *M*-3, energizing the output circuit and causing conveyor 1 to run to the right.

When the conveyor actuates limit switch *LS*-2, one input is provided to AND unit A-4. The other input is already present because memory unit *M*-1 has remained in the OFF state. AND unit A-4 gates an output and turns OFF memories *M*-2 and *M*-3. Conveyor 1 stops and reverses, moving to the left until LS-3 is tripped, at which time it stops.

If both boards are good and the selector switch is still in the "normal" position, the operator presses the "no-waste" button. This provides one input to AND unit A-1. The other input is already present from the normally-closed contact on limit switch *LS*-4, and AND unit A-1 gates an output, turning memory unit *M*-1 ON. This means that when *LS*-2 is first tripped by the conveyor dog only one input is present for AND unit A-4 and memories *M*-2 and *M*-3 are not turned OFF, so the conveyor keeps moving to the right past limit switch *LS*-4. When *LS*-4 is tripped, memory unit *M*-1 is turned OFF. Now the next time *LS*-2 is tripped, both inputs to AND unit A-4 will be present and memory units *M*-2 and *M*-3 will be turned OFF, deenergizing the output circuit. Conveyor 1 will stop and reverse, moving to the left until *LS*-3 is tripped.

If the selector switch is in the "no-reject" position, the operation will repeat without pressing the "no-waste" button for each pair of boards. This is because limit switch *LS*-1 turns on memory unit *M*-1 each time it operates, so that only one input to AND unit A-4 will be present the first time *LS*-2 is tripped. Limit switch *LS*-4 will then turn memory unit *M*-1 OFF, so that both inputs to AND unit A-4 will be present the second time *LS*-2 operates during a cycle. AND unit A-4 gates an output, deenergizing the output circuit. NOT unit *N*-1 turns all memory units OFF if power fails.

Figure 23 shows one of the band saws and resaw conveyors at the Lutcher & Moore sawmill. The left-hand control panel in Figure 24 contains the Westinghouse Cypak system for the horizontal resaw outfeed conveyor control just discussed.

To a warehousing conveyor

GE has applied its ICD static switching equipment to an extensive conveyor control system at a large eastern appliance plant. Six products of three buildings are delivered to a warehouse, where the conveyor divides into nine spurs leading directly to rail and truck loading platforms and to storage areas.

One of the interesting features of this system is the use of a shift register, a technique borrowed from the digital computer field. Since the conveyor is sectionalized, the information concerning the relative position of parts moving along the conveyor must be retained as the items move from one section to the next. This can be done in a shift-register logic system such as shown in Figure 25.

Assume that an ON signal is applied to the left-hand element in Figure 25A (one of the multi-purpose units in the ICD line). With a bias of minus-one unit, the output *M* appears as soon as the ON signal of plus-one unit is applied. Feeding back the *M* output to another ON input terminal makes sure that the ON state is remembered even after the original ON input signal is removed. Now the problem is to shift the ON state from the left-hand to the right-hand unit.

This can be accomplished by applying *SHN* signal to the green unit and to one of the ON terminals of the blue unit. This shift-to-*N* signal, along with the *M* signal, provides two positive units of signal to counteract the minus-two units of bias. Thus the unit switches ON and gives the *N* signal. This signal is fed back around to the third ON input of the blue unit and provides an additional positive signal to hold this unit ON after the *SHN* signal is removed. There is a short time delay in the green unit before signal *CM* appears at its output. This cancel-*M* signal turns OFF the left-hand multi-purpose unit and signal *M* disappears. However, *N*, the blue-unit feedback signal, is applied at an input terminal that has a lower value of resistance than the other input terminals, and provides two positive signal units. Even after signals *M* and

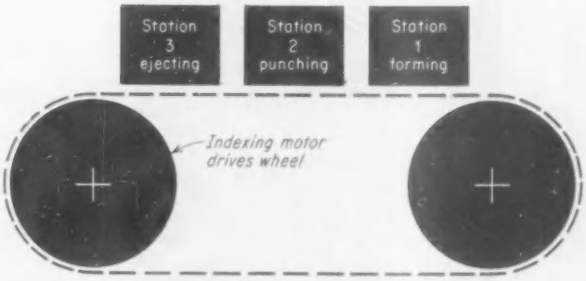


FIG. 27. Schematic of index chain mechanism used on three-station machine for fabricating oil filler caps. GE GPCD static switching control is used on this A-C Spark Plug machine.

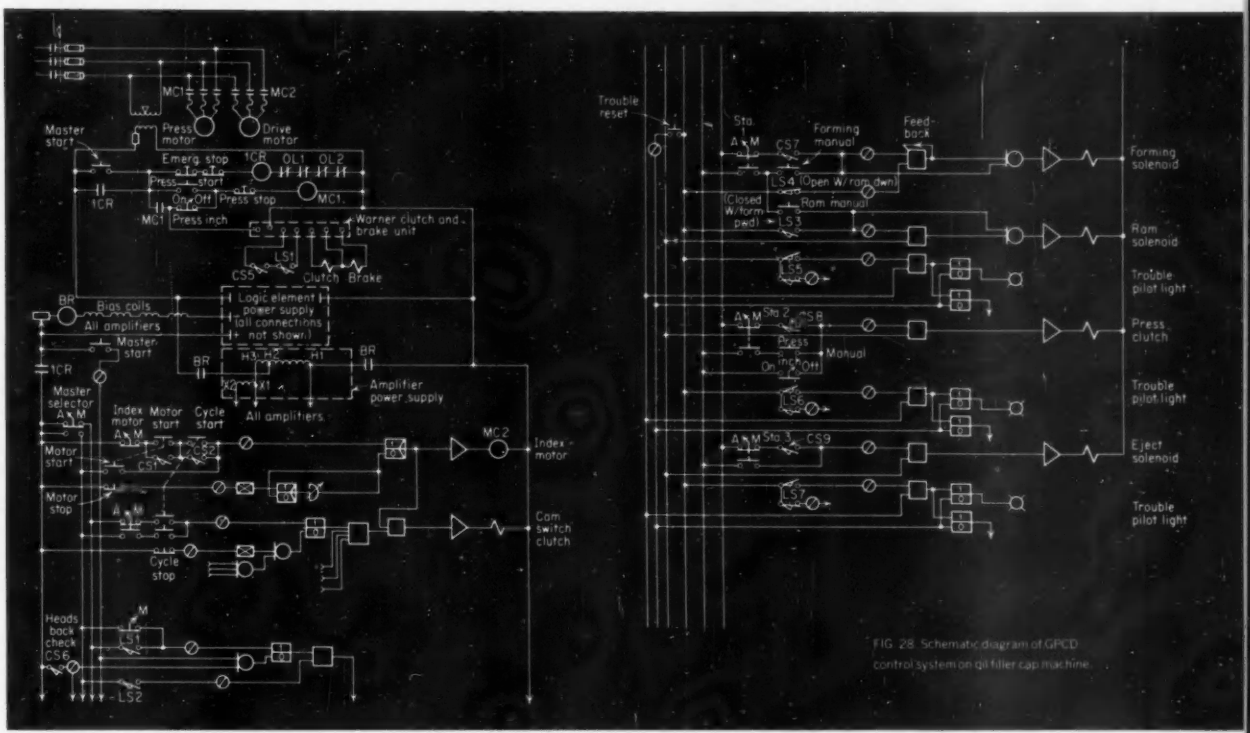


FIG. 28. Schematic diagram of GPCD control system on oil filler cap machine.

FIG. 29. Two-input AND unit being plugged into base receptacle in GE GPCD static-control simulator.

FIG. 30. GE engineers simulate circuit to be used to control A-C Spark Plug machine on static-control simulator.

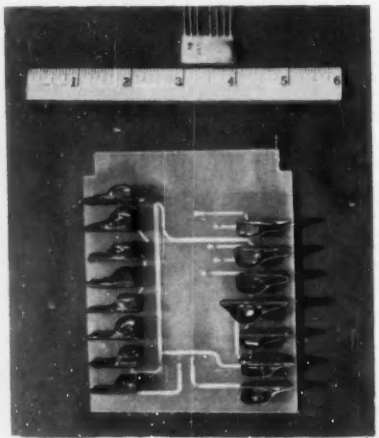


FIG. 31. Westinghouse transistor NOR units mounted on printed-wiring board. The larger NOR units on the board will handle six separate inputs.

SHN are removed, this higher-level positive signal holds the unit ON. Note that the cancel-N signal, *CN*, is required to turn the blue unit OFF when the information stored in this device is shifted to a subsequent unit. These units are connected to the permanent memory portion of the static-switching-system power supply. Thus, after loss of power or normal shutdown of the conveyor system, the information specifying the location of each item is remembered when power is reapplied.

Figure 25B shows the electromechanical relay circuitry that would be required for this job.

This GE conveyor system uses the binary code to identify each part within a given section. With a four-binary output, there are 16 possible combinations of output signals, yielding a numbering system of zero through 15. This can be done by designating the four static-memory devices as code one, code two, code four, and code eight.

How can this code be used in a shift-register system for conveyor control? Assume that part 11 is to be retained when it reaches shipping area G. In the first section of the conveyor, the binary code for this part is established on the static devices by turning ON a code-one, a code-two, and a code-eight static memory. As the part moves along the conveyor, this code is shifted, registered, and canceled—section by section—until the part reaches shipping area G. At this point, a signal is sent from the control panel to remove part 11 from the conveyor. The part is retained and the signal canceled.

Figure 26 shows the ICD conveyor control panel, with monitor lights attached to each module. These lights, extremely useful in checking the movement of items along the conveyor system, can indicate a pile-up or other trouble, and the section of the conveyor where the trouble has occurred.

To a sheet-metal fabricating machine

A GE GPCD pulsed-power-supply static switching system has been applied to a crank-case-breather straight-line assembly machine of the A-C Spark Plug Div. of General Motors. This equipment fabricates oil filler caps for automative use, where the engine crank case and internal engine spaces "breathe" through an air filter in the oil filler cap. The machine has three stations: for forming, punching and ejecting, Figure 27. A chain consisting of a series of plates spans the three stations. An indexing motor of the Warner-Ferguson-drive type indexes the wheel that drives the chain. A clutch-driven cam switch, the clutch engaged and disengaged by a solenoid, is associated with the drive.

Contacts in the cam switch, together with the head-rest-position limit switches in each station, determine whether the work head has returned to its rest position. If any head does not return by the time the cam switch contacts close, the cycle is halted and cannot be restarted unless the "trouble reset" and "cycle start" buttons are pressed.

Figure 28 shows the logic circuitry for this system. The left-hand portion of the diagram handles the drive and indexing functions, the right-hand portion the station-operation functions. Several electromechanical contactor devices are used, in applications where they operate only infrequently or where high-power circuits must be closed. In particular, note relay *BR*, with its coil in series with the bias coils of all the logic units. As was pointed out previously, all bias coils are in series in the GPCD system and provide for power supply turnoff if one should open. In this case, the job is done by the normally-open contacts of relay *BR* in the input power leads to the amplifier-power-supply unit. If a bias coil opens, relay *BR* is deenergized, opening the leads.

Before this system was designed into a panel, the logic circuitry was tested on a simulator. Figure 29 shows a two-input AND element being plugged into the base receptacle in a GE GPCD static-control simulator. The clip-on monitor lights can be seen as well as the recessed portion in the base receptacle. The units without nameplates in the bottom two rows on the left are jumper plugs for bringing in power connections to the printed circuit in the base receptacle. Figure 30 shows the complete simulator, wired as a duplicate of the A-C Spark Plug panel, even to the amplifiers in the foreground.

Both Westinghouse and GE have found static control simulators invaluable in checking and debugging systems before they are designed into panels and put into operation. In fact, many potential big users of static switching systems have acquired their own simulators, both to check out their own designs in cases where they purchase components instead of complete systems, and to train their personnel in design and maintenance.

To a furnace-charge recording system

Westinghouse has used its transistor NOR circuit of Figure 14[14] in a steel-industry application for counting and recording the number of billets that are charged into a furnace. Fully described by Stringer and Rowe in Reference 15, this system uses phototransistor input sensing devices and transistor-NOR logic elements to count randomly-positioned billets on a furnace-charging conveyor.

Figure 31 shows 15 of the transistor NOR units mounted on a printed-wiring board. Each unit contains the transistors and associated rectifiers and resistors. This device has proved useful not only in industrial switching applications, but also as a standard component for digital computer use.

USEFUL SYSTEM DESIGN HINTS

Manufacturers of static switching devices are taking great pains to make sure that their equipment is properly evaluated with respect to older and better-known switching devices. For some time now, at least one manufacturer has operated a special course to teach the engineers of prospective users where to use static switching elements and the basics of system design. To an engineer totally unfamiliar with these techniques this is certainly time well-spent, since it appears that almost everyone now involved with industrial switching will be called on in the future to design, or at least recommend, static switching systems. Most engineers equally acquainted with relays and static switching feel that static systems are easier to design and debug.

If a static switching system is being designed to take the place of an existing relay system, the problem of system synthesis is considerably simplified. If a completely new switching system must be developed, the problem is not unlike that of synthesizing a conventional relay system. First examine the mechanical layout to determine the required outputs (solenoid valves, motor starters, etc.) and the type and number of input sensing devices (limit or cam syitches, pushbuttons, etc.). Then tabulate the input conditions that will yield each output (including safety features) for the most automatic cycle of operation. Input-condition tabulations such as given in Table II are useful here. Tabulating sequential operations is more difficult and requires flow charts or other diagrammatic aids. The tabulations can be simplified to word logic statements, which are checked for operational accuracy on a simulator. Usually the logic circuitry needed for single-cycle and manual operation is added last.

Designers, even those with little experience, have found that it is fairly easy to make changes in design even after a system is built. "On the spot" changes are often made with little change in wiring and no change in panel layout.

WHAT DO STATIC SYSTEMS COST?

At present, the average static switching system costs more than a corresponding electromechanical relay system. A number of power output amplifiers corresponding to the number of output devices is required for the static switching system. The logic is performed at fairly low power levels, but the output must be amplified to drive the usual solenoids, contactors, etc. The logic devices are reasonably priced (about $10 apiece), but the output amplifiers are very expensive ($50 to $100 apiece).

Another factor in the cost picture is the special power supply required for a static switching system. The cost of the logic-system power supply is almost constant for up to 100 logic units. Hence, if a system requires a large number of logic units, the cost of the power unit per logic unit is low, but if there are only a few logic units, the relative cost of the logic power supply is high. The GE ICD conveyor control system shown in Figure 29 uses about 200 logic units and only 19 small power outputs, and its cost is less than an equivalent relay-control system. Two very general conclusions can be drawn concerning the relative cost of static and electromechanical switching systems:

1. Simple static systems are expensive because of the high cost of the special power supply serving only a few logic units.
2. Static systems with a large number of outputs relative to the number of inputs and logic elements are expensive because of the high cost of power amplifiers.

Of course, the first cost of a static switching system versus the first cost of a corresponding electromechanical relay system may not be too meaningful. Maintenance expenses and the somewhat intangible value of reliability and continuity of service are also important, sometimes many times more important than first cost. Installations of static switching systems have been made where the prevention of one unscheduled shutdown because of control failure would pay for the complete switching system many times over.

INPUT AND OUTPUT PROBLEMS

The unsuitability of available input devices has contributed to the reluctance of many engineers to use static switching systems. At present, the input must usually be stepped down from the voltage level required across mechanical contacts, such as pushbuttons and limit switches. Although the procedure requires additional equipment, this is not too big a stumbling block since the power level at input is very low and the initial input transformers or voltage dividers can usually be small and relatively inexpensive. A bigger problem, as pointed out in a previous section, is the unreliability of conventional limit switches.

Some contactless proximity limit switches are available today, but all seem to suffer from large size, high cost, and poor repeatability. If a planer is operating up against a shoulder, the limit switch must be reliable and must accurately repeat its operating point. Again, imagine equipping a machine with 40 limit switches at $100 to $150 a switch! Many manufacturers, such as Westinghouse, the Boston Div. of Minneapolis-Honeywell, Square D, etc., are working on this problem and strides have been made toward the development of suitable switches. Contactless pushbuttons and other types of input devices are also being developed. Many of these, of course, will eliminate the problem of voltage transformation at input.

In the past the users of some static switching systems found that the output magnetic amplifier could not properly drive some of the solenoid operated valves. In general this was because the magnetic amplifier could not provide sufficient inrush current to assure complete and positive movement of the solenoid armature. Today both Westinghouse and GE are developing amplifiers to solve this problem.

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Robert A. Mathias

Robert A. Mathias holds at the ripe old age of 30 a PhD in electrical engineering (his thesis was on multistage magnetic pulse generators) and an assistant professorship in EE at Carnegie Tech. Inherent in all this is an undisputed qualification as an authority on static switching devices.

After receiving a BS in EE from the University of Colorado in 1947, Mathias joined the Special Products Dept. of Westinghouse Electric Corp., where he worked on feedback control systems. An MS in EE from the University of Pittsburgh followed in 1949, and in September of that year he left Westinghouse to go to Carnegie Tech as a teaching assistant and candidate for a PhD. Two years later he was working on magnetic-amplifier and magnetic-pulse problems as a full-time research engineer, and four years after that came the PhD. He continues to consult on magnetic amplifiers and static switching systems.

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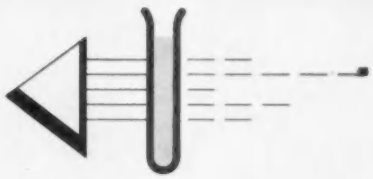


ANALYSIS INSTRUMENTATION...

. . . a key factor in optimizing industrial processes

Analysis instrumentation, an important factor in the efficient and high-quality production of gaseous, liquid, and solid products, is employed in control laboratories by virtually all processing industries. Advances in both analysis instruments and control methods has, however, resulted in many cases in automatic process control based on product quality. But many analysis instruments have not yet been developed to the point where they can be used for process controls.

This article sketches briefly the fundamental methods of analytic measurement, the types of outputs obtained with analysis instrumentation, and the control methods that can be used with these outputs. Also discussed are the problems of sample-handling and of correlating the desired product to specification with the analysis technique, and the role of computers in interpreting analysis data.

Future articles in this new series will cover the important techniques and instruments in greater detail. Typical are the articles coming up in the next two months on nuclear magnetic resonance and chromatography, which will cover fundamental phenomena, describe equipment basics, and, where relevant, examine an application of the instrument to process control.

HARRY R. KARP, Control Engineering

Industrial processes convert feedstocks, which are usually natural materials that vary in their composition, into desired products of fixed specifications. Some products coming out of processes contain perhaps one, two, or three components, others 20 or more components. A knowledge of process-stream components is important because then the specification of the desired product can be stated in terms of composition.

Analysis instruments show materials in terms of their components in the stream and their concentrations. They develop signals indicating the materials composition, and these signals, tied into the control of such process conditions as temperature, pressure, and flow, give prompt correction of deviations from product specifications.

Measurement and control of process conditions assure plant stability, and thus a satisfactory, but not necessarily optimum, product. The varying composition of the feedstreams, the increased costs of plant, raw materials, and labor, and the higher prices received for premium products, however, make an optimum product mandatory. Analysis instruments bridge this gap.

Any decision involving analysis instrumentation should be guided by economic considerations and technical familiarity. Anticipated improvements, equipment, installation, and maintenance costs, depreciation, return of investment, etc., are all part of the economic picture. If a process has a throughput valued at $1 million a year and analysis instruments can upgrade the yield by even one-half percent, the investment becomes attractive indeed.

However, if anticipated economic gains are to be met, sound technical solutions must be found to the

Fig. 1. Continuous output signal

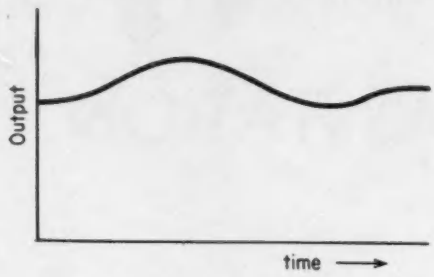
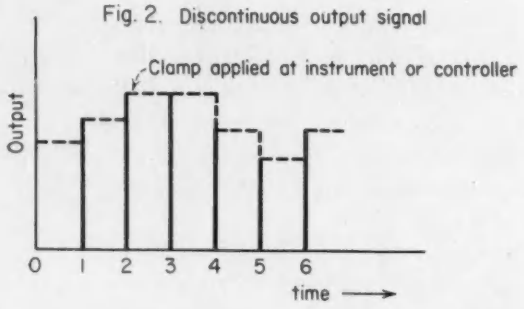


Fig. 2. Discontinuous output signal



problems that arise in instrumenting the analysis techniques and installing the instruments in the plant. An intimate knowledge of the process and of the desired and undesired components in the product, proper selection of the most suitable instruments, attention to sample-handling problems, to maintenance, reliability, and possible hazards, and to accuracy and sensitivity requirements are some of the things that must be considered.

Fundamental analysis methods

Analysis instruments employ a wide variety of measuring techniques, each of which determines some fundamental property of a sample in the process stream. These instruments are classified as specific or nonspecific and continuous or discontinuous.

The following list shows fundamental methods and their subclasses for analyzing process streams. Since each subclass may have several variations, there are well over 100 instrumental techniques, though not all are for in-plant measurement and control.

- ▶ Radiant energy properties
  - • absorption spectrometry— visible, ultraviolet, infrared, and x-ray
  - • refraction and dispersion
  - • emission spectrometry
  - • nuclear magnetic resonance
  - • electron paramagnetic resonance
  - • ionizing radiation
- ▶ Electrical properties
  - • dielectric constant
  - • magnetic susceptibility
  - • conductimetry
  - • electrolysis
  - • electrolytic conductivity
  - • electromotive force (pH)
  - • voltammetry
  - • polarography
- ▶ Mechanical properties
  - • viscometry
  - • specific gravity
  - • velocity of sound
  - • absorption of sound
- ▶ Thermal properties
  - • thermal conductivity
  - • transition temperatures
  - • heats of reaction
- ▶ Chromatography (vapor fractometry)
- ▶ Mass spectometry

Continuous or discontinuous

In continuous instrumentation a continuously-flowing sample is diverted from the stream and introduced into the instrument, which measures its property (essentially) instantaneously, and then sends it back to the stream or discards it. (When the sample is properly handled the sample conditions represent the stream conditions.) Measurement of the property, such as refractive index, is continuous, and a continuous and instantaneous indication of the measured value is presented with respect to time, Figure 1.

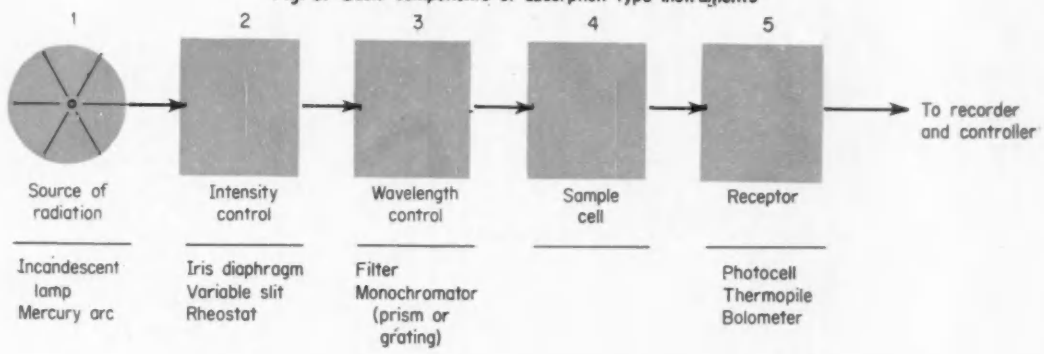
In discontinuous instrumentation a discrete sample volume is taken from the stream, introduced into the instrument, and held stationary while an indication is made available for it. Sometimes it is treated with a reagent to make the reading more specific and sensitive. Later another sample is taken and measured, and so on, so that indications are discontinuous with respect to time. Nuclear magnetic resonance instruments, for instance, when analyzing a discrete sample for moisture content yield discontinuous readings, Figure 2.

It is quite possible that the input sample will flow continuously and that the instrument output signal will be discontinuous. Stating the continuous or discontinuous nature of both input and output becomes important, particularly for automatic process control, because continuous output signals, for instance, lend themselves to conventional on-off and proportional-control systems, while discontinuous outputs are suited to sampled-data time-sharing controllers.

Specific or nonspecific

Specific analysis instruments respond only to changes in concentration of the component the instrument is designed to measure. Nonspecific

Fig. 3. Basic components of absorption-type instruments



instruments respond primarily to the concentration of the component of interest, but also (to a lesser degree) to other components. One specific analysis technique is the measurement of pH. The pH instrument indicates hydrogren ion concentration only; the presence of other ionic components in the stream does not interfere with the reading. A refractometer is a nonspecific instrument: refractive index does not, in general, indicate sample composition; rather, the product-sample refractive index is compared with the refractive index of a reference sample meeting product specifications.

The specificity of measurement can be improved by removing interfering components, by changing the phase (liquid, gas, or solid) of the sample, by using filters to select radiant energy in a certain narrow band of wavelengths, and in other ways. In general, nonspecific instruments are not too successful for analyzing products with more than two key components.

Absorption spectrometry

Analysis by the radiant-energy method depends on the interaction of atoms or molecules in the sample with radiant energy from a source. In absorption spectrometry, one of the important and widely-used subclasses of this fundamental method, a source such as a heated tungsten filament radiates energy over a range of wavelengths. The energy is directed at the sample, Figure 3, on the other side of which is an energy detector such as a photocell. The sample interferes with the transmission of energy more at certain frequencies than at others. That is, it absorbs energy. The frequencies of maximum absorption identify the composition and the peak amounts indicate the concentrations of each component.

There are two basic variations: the absorption is measured over the whole range of wavelengths, or the source energy is separated into discrete or narrow bands of wavelengths, as by a prism or diffraction grating, and the absorption is measured at each wavelength. Instruments for the first variation, such as infrared and ultraviolet double-beam dispersive analyzers, compare the process sample with a sample of satisfactory product. These instruments usually have limited specificity. Instruments for the second variation, such as infrared and ultraviolet spectrophotometers, identify sample components that absorb strongly at narrow wavelength bands. These can be considered to be highly specific.

Mass spectrometry

Mass spectrometry, another important analysis technique in the processing industries, is particularly well-suited for analyzing liquid and gaseous samples. The sample is first bombarded and fragmentized by a stream of electrons which ionizes and imparts a positive charge to the sample particles of all components. A high voltage accelerates the positively-charged ions while a magnetic field simultaneously fans out the ionized particles into discrete beams, so that particles with differing mass-to-charge ratios follow circular paths with differing radii from the source to a collector plate, Figure 4. The fragmentized components in the sample are identified by determining their mass-to-charge ratios.

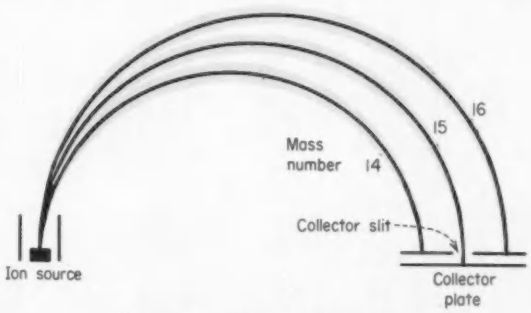


Fig. 4. Dispersion of ionized particles according to mass number

Another plate, with a narrow slit between the ionized beams and the collector plate, admits only particles of a certain mass-to-charge ratio through the slit to the collector plate. The slit can be moved to the beam associated with the particular fragment, or what is more practical, the slit can remain in one

INSTRUMENTS AND TECHNIQUES FOR ANALYZING PRODUCTS*

C. M. ALBRIGHT, E. I. du Pont de Nemours & Co., Inc.

INSTRUMENT OR TECHNIQUE	ANALYSIS OF—	ANALYSIS FOR—	TO DETERMINE INDENTITY—	TO MEASURE QUANTITY—	SAMPLING REQUIREMENTS	LIMITATIONS	SPECIFIC OR NONSPECIFIC
COLORIMETRY, reflected or transmitted light	Gases, vapors, liquids, solutions, slurries, and solids.	Dyestuffs, pigments, color indicators, and other substances whose reflectance or transmittance in visible light is characterized by any dispersion vs. wavelength.	Not necessarily determined. Color is specified, however, by measurement of relative reflectance or transmittance value vs. wavelength over visible range. Approximations to identity are made by taking measurements at a number of wavelengths, or by filter colorimetry wherein the response to light defined by specially-designed filters is measured.	Strength of color is determined by measuring amount of light reflected or transmitted at the wavelengths of peak absorption compared with an absolute or standard white.	Samples can be liquid in cells, painted panels (wet or dry), and woven fabrics. Amount varies widely. Sample preparation may require considerable study.	Sensitivity approximates that of human eye.	Nonspecific
DIELECTRIC CONSTANT (dielectric loss)	Liquids, solutions, and suspenions.	Substances of high dielectric constant or loss in presence of background having low dielectric constant or loss, such as water in organics, and polar molecules in nonpolar solvents.	Not specifically determined except by inference.	Change of frequency of tuned circuit (or required change in tuning of circuit or voltage change across circuit) containing sample as dielectric in capacitative element.	Sample should be clean, low in conductance, and nominally regulated in temperature. Rf measurements with noncontacting electrodes should be used for corrosive samples.	Applicable only to binary and some ternary systems.	Nonspecific
EMISSION SPECTROSCOPY	Gases, vapors, liquids, solutions, suspensions, slurries, particulate solutions, and solids.	Most elemental constituents of any sample. Especially suited for control analyses of minerals, metals, and alloys.	Sample is destructively bombarded by arc or spark to produce radiation of constituent atoms by changes in electron energy levels. Radiation distribution is analyzed by wavelength distribution in spectrometer, producing characteristic patterns of each element.	Amount of radiatian at characteristic wave lengths can be related to abundance of each element.	Sample must be contained in arc or spark source. Electrodes must be of known purity. Special sample preparation facilities usually required.	Can be used to identify 70 elements.	Specific
INFRARED ANALYZER (double-beam dispersive type)	Gases, vapors, liquids, solutions, and thin-film solids	Any heteroatomic molecule: specific wave length, based on separate spectrophotometric data for each analysis. With such data, performance can be predicted.	Not determined except by inference. In a particular case, if a pair of infrared wavelengths can be found, one of which is not affected by variation in any constituent and one of which is absorbed only by sought-after component, then analysis can be specific for that component.	Measurement of relative amount of infrared radiation transmitted through sample with respect to radiation not affected by measured component.	0.1 to 0.5 cfm of clean, dust-free sample. Must be free of condensate that might deposit in sample cell.	Sensitivity affected by presence of interfering substances.	Nonspecific
MASS SPECTROMETER (magnetic analyzer)	Gases, vapors, liquids, solutions, and, with proper sample handling, some solids.	Atoms, molecules, and free radicals, and their reaction products. Specialized instruments sensitized to He are widely used as leak detectors.	Ionized fragments of sample are separated on basis of momentum by accelerating them with an electric field and deflecting their path with magnetic field so that a specific mass strikes ion collector. Instrument is qualitatively specific.	Ion current, when amplified, is proportional to relative abundance of ions having selected mass, and can be related, for a given instrument, to the quantity of parent molecules in sample.	Sample admitted to system at very low pressure, about 10^{-4} mm Hg, usually fractionated through molecular leak; for continuous analysis, however, viscous leak is employed.	Mass resolution obtained at expense of sensitivity.	Specific
NUCLEAR MAGNETIC RESONANCE	Gases, vapors, liquids, solutions, suspensions, slurries, particulate solutions, and solids.	Any molecule or atom possessing nuclear spin. Characterization and study of interatomic bonds. Is least suited to O_2 among the commonly encountered elements.	Measurement of radio frequency which differs for each nucleus having spin at which nuclei precess in a magnetic field of known strength. Frequency and field strength at which rf is induced in detector coil owing to precession resonance is characteristic of any particular nucleus.	Relative amount of rf induced or coupled from transmitter coil to detector or receiver coil is proportional to concentration of resonant nuclei per unit volume of sample cell.	Any kind of sample is satisfactory, although liquids are generally preferred. Nuclear density is less in gases, giving smaller signal, and resonances are broadened owing to structural interactions in solids. Temperature must be controlled.	Not applicable to nuclei without spin.	Specific
pH (hydrogen-ion concentration)	Liquids, solutions, suspensions, and slurries.	H^+ (or H_3O^+) content in liquids.	(a) Selective potential developed across glass-electrode membrane permeable only to H^+ ions; (b) solution potential developed in redox system affected by H^+, such as quinhydrone or antimony electrodes; (c) colorimetric methods employing pH-sensitive color complexes.	Magnitude of electrode potential as measured by sensitive voltmeter is related to $-\log(H^+)$. For each tenfold increase in H^+, the potential of all measuring systems changes 59.1 mv.	Sample can be static or flowing. Temperature has inherent effect on pH as well as on electrode response and should be controlled or known.		Specific
RADIOLOGICAL GAS ANALYZER (ion chamber analyzer)	Gases and vapors.	Detection of gases having high electron density in gases of low electron density, or vice versa, such as argon or ammonia in nitrogen.	Not specifically determined except in tailored applications where interfering gases are removed.	Relative ion current produced in two symmetrical chambers exposed to equal amounts of beta radiation depends on average electron density, or atomic number, of the gases in the two chambers.	Sample must be clean, dry, and temperature-controlled. Interfering substances must be removed by absorption.	Applicable only to binary systems.	Nonspecific

REFRACTIVE INDEX (differential type)	Liquids, solutions, and sometimes gases and vapors.	Optically transparent, nonfouling binary solutions, such as salts, acids, and bases; hydrocaroons, such as alcohols, ethers, acids, phenol, glycerine in water; and sugars, fruit juices, and oils.	Not determined. Sample is assumed to be identical in composition with standard when refractive indices coincide.	Difference in refractive index of sample from that of reference standard is measured, using photoelectric detectors, in terms of displacement of optical beam that passes through -prism-shaped vessels containing both sample and reference.	Sample must be clean; that is, free of suspended solids, and relatively constant in temperature. Flow can be 100 to 500 ml/min.	Applicable to binary and some ternary solutions that transmit appreciable light.	Nonspecific
SOUND VELOCITY	Gases, vapors, liquids, solutions, suspensions, slurries. and solids.	Composition of two-component systems wherein sound velocity differs widely owing to difference in molecular weight.	Absolute sound velocity is physical constant permitting identification of pure gases, liquids, and solids. Composition of mixtures not specifically determined.	Sound velocity through mixture is proportional to mean molecular weight, so that electrical measurement of transmission time of sonic wave or phase shift through sample can be related to proportions of two constituents.	Not critical; inlet and outlet for fluid samples must not interfere with sound-wave propagation. Sample temperature is critical and must be closely regulated.	Chiefly applicable to binary systems.	Nonspecific
THERMAL CONDUCTIVITY	Gases and vapors.	H_2, CO_2, acetone, Cl_2, He, H_2, SO_2, and H_2S in air, and sought-for gas wherever it differs widely in thermal conductivity from background gases.	Not specifically determined by thermal conductivity alone. Associated techniques, such as selective absorption, may be employed for enhancing selectivity.	Proportional to thermal conductivity of mixture as determined by cooling effect on heated wire in chamber into which sample gas diffuses. Effect on heated wire measured electrically with respect to similar wire in enclosed chamber not open to sample.	Sample must be clean, dry, and free from suspended particles. Generally should be noncorrosive. Flow should be carefully regulated, as well as absolute pressure of sample.	Generally limited to binary systems, but can be used for others, particularly where sought-for component has heat capacity widely different from remaining components.	Limited
ULTRAVIOLET SPECTROPHOTOMETER (single- or double-beam)	Gases, vapors, liquids, solutions, and sometimes thin-film solids.	Aromatic and other double-bonded organic materials, such as acetone, benzene, carbon disulfide, halogenated hydrocarbons, Cl_2, ozone, NO_2, and SO_2. Also rare earths, free radicals, and many biological materials.	Pattern of ultraviolet absorption vs. wavelength is specific for most materials showing strong absorption peaks.	Measurement of amount of radiation absorbed in any one of the wavelengths specific to the sample component sought, with respect to the incident radiation at the wavelength of measurement, corresponds to concentration according to Beer-Lambert Law.	Laboratory instruments accommodate samples of 10 to 100 ml, depending upon length of sample cell necessary. Not usually employed for continuously-flowing samples.		Specific
VISCOSITY	Liquids, solutions, suspensions, and slurries.	Concentration of heavy solutions and suspensions, molecular weight of polymer melts and solutions, and grading of petroleum products.	Determined only insofar as viscous properties are characteristic.	Techniques vary widely, including rate of fall of objects through sample, discharge rate through orifice, pressure changes across orifice or capillary, retarding torque on rotating or oscillating surface, displacement of bob in tapered tube, and damping of oscillating probe.	Vary widely.	Varies widely.	Nonspecific
X-RAY ABSORPTION	Gases, vapors, liquids, solutions, and solids.	Heavy elements in light elements, regardless of chemical composition. Usually not applicable to atoms of atomic weight less than sulfur. Good for lead in gasoline.	Not specifically determined except in instruments employing filters or crystal monochromators to isolate x-ray wavelengths specifically located adjacent to a "critical absorption edge" of the element being sought.	Ratio of x-ray intensity in absorbing path to that in reference path, as determined by relative counting rate in Geiger-counting-tube detector.	Sample cells usually must be very thin and have windows relatively transparent to x-rays, such as Al. Plastics are sometimes useful.		Limited

*From a table of over 100 analysis instruments and techniques to be included in PROCESS INSTRUMENTS AND CONTROLS HANDBOOK, edited by D. M. Considine; a forthcoming publication of the McGraw-Hill Book Co., Inc.

position and the accelerating voltage adjusted to vary the radius of the selected beam. Either way, only the ionized beams associated with each sample fragment go through the slit. Varying the accelerating voltage over a range of values allows the mass spectrometer to select sequentially the fragments of each component present in the original sample. The ions striking the collector plate develop an electric current proportional to the concentration of the selected fragment.

Output signals

Recall that in an infrared analyzer, where the absorption of the flowing product is compared with the infrared absorption of a reference sample, the electrical output signal will be a continuous function of the absorption difference with respect to time, Figure 1. This continuous output feeds into an on-off or proportional controller to correct any deviation in absorption from specification. An alternative is to sample the continuous output in successive time intervals; this results in the type of signal shown in Figure 2. The sampled signal feeds into a sampled-data controller.

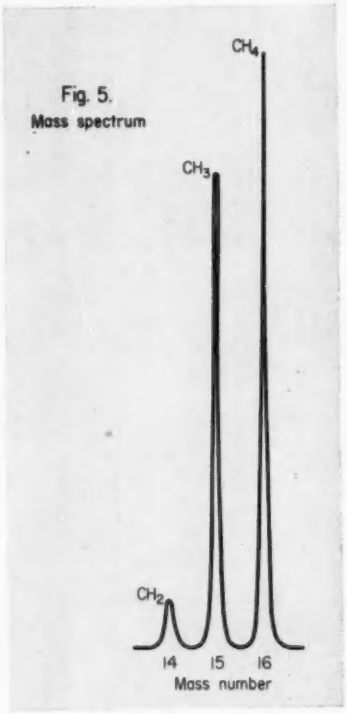


Fig. 5.
Mass spectrum

Output signals obtained from a mass spectrometer contain additional information. Since the mass spectrometer can be tuned to determine the concentration of one component only, it can give a continuous output voltage as a function of a discrete or continuously-flowing input sample, Figure 1. Thus, the output signal can be used in closed-loop control to continuously adjust the process and maintain the concentration of that component at a specified level. (Analysis instruments are frequently sensitized to detect the presence of an impurity; if one exists, the control system corrects the process to minimize, below allowable limits, the amount of the impurity present in the stream.)

The mass spectrometer can also be adapted to determine several mass numbers in one product sample. The instrument captures for an increment of time a discrete sample and the accelerating voltage is adjusted continuously to determine the concentration of all mass numbers of interest. The resulting plot, Figure 5, is a spectrum showing concentration vs. mass number.

Spectra can also be obtained by several other techniques which yield plots of concentration vs. the variable that forms the basis for the technique. Thus:

- concentration vs. wavelength—absorption spectrometry
- concentration vs. time—chromatography
- concentration vs. magnetic field strength—nuclear magnetic resonance

When the sampled-data system controls the concentration of one component only, the controller can be relatively simple. But when fixed ratios of components and a minimum amount of impurity are demanded of the process, the sampled-data controller must be time-shared and have internal or external computing functions.

Spectral records, such as those shown in Figure 5, contain much useful information. Each component shows up as a peak at a unique place (here a given mass number), and knowing the mass numbers of all components present identifies the stream composition. The area under the curve of each peak is related to the percentage of that component to the overall sample. When the curves are symmetrical, as is assumed in the following section on computing, the percentage can be related to the peak heights of the component curves. Many products contain 15 or 20 components, but only a few key mass numbers may be important. Then the spectral instrument may be programmed to skip all components except the key ones. This speeds up analysis time and allows more frequent sampling.

Sometimes in the mass spectrometer analysis of a complex hydrocarbon mixture different molecular components are present. Suppose each of three components fragmentize into different proportions of ions: CH_2^+, CH_3^+, and CH_4^+. When the ionizing beam bombards the complex molecular mixture it breaks down each component into CH_2^+, CH_3^+, and CH_4^+, and the peak height at each mass number indicates the concentration of each ion. What must be determined, however, is not the concentration of each ion in the complex mixture, but the concentration of each of the components making up the original mixture. This calls for computing.

The percentage, or more accurately the mole fraction, of each component can be found by first calibrating the instrument against a pure standard sample of each component and finding the peak height of each mass number present. Then the product sample is analyzed and the peak height determined for each mass number. The information is next put into the following form:

$$\begin{aligned} F_1 A_a + F_2 B_a + F_3 C_a &= P_a \\ F_1 A_b + F_2 B_b + F_3 C_b &= P_b \\ F_1 A_c + F_2 B_c + F_3 C_c &= P_c \end{aligned}$$

where F_1, F_2, and F_3 are the mole fractions of each

molecule in the product sample under analysis.

A_a, A_b, and A_c are the calibrated amplitudes of standard component A at mass numbers a, b, and c

B_a, B_b, and B_c are the calibrated peak heights of component B at mass numbers a, b, and c

C_a, C_b, and C_c are the calibrated peak heights of component C at mass numbers a, b, and c

P_a, P_b, and P_c are the peak heights of the complex mixture at mass numbers a, b, and c

The solution of the simultaneous equations by determinants yields the desired values of the mole fractions F_1, F_2, and F_3. A third-order determinant can be solved manually, but this becomes rather tedious and time-consuming when there are repeated analyses. Besides, the time-delay would be too great for closed-loop control systems. Computers yield the desired answers in fractions of a minute and minimize the time delay.

Systems have been developed for programming and detecting as many as 15 or 20 components on a mass spectrometer, converting the peak heights of each mass number into a digital number, simultaneously typing them on a log sheet and punching paper tape, and then feeding the tape into a digital computer which solves the determinant and types out the complete mole fraction analysis of the sample. This arrangement has not, as yet, been integrated into a closed-loop process control system.

Sample-handling

The sample introduced into the analyzer must be typical of the process stream. Houser[1] states in this respect that a sampling system should take a representative sample from the stream, transport it to the analyzer, and act upon it either physically or chemically to put it in a form ready for analysis.

A sampling system must therefore have a properly-located sample point, and must prevent composition changes resulting from sampling, use a sample-flow rate consistent with the amount of sample economically withdrawn and with the dead time affecting controllability of the process, and use an appropriate sample volume. Other things the system should do: maintain sample pressure as needed for adsorption instruments; maintain constant temperature, as in chromatographic columns; pretreat the sample to remove interfering components and to condition it for analysis; remove contaminants; and prevent gas and vapor samples from condensing in the sampling system.

The sampling system thus introduces as many, if not more, design problems as the analysis instruments themselves.

Correlation

Control of a product by manual or automatic means requires a correlation between desired product specification and the analysis method and instrument used to measure the composition. Consider, for example, the separation of hydrocarbon mixtures, where it has been found empirically that the optimum overhead product can be related to the concentration of a key component in the column.

The concentration of the key component may be determined by measuring any of several properties, such as viscosity, refractive index, ultraviolet absorption, or mass number. Tests of concentration changes vs. changes in these properties requires an engineering compromise between:

- sensitivity (steepest slope on plotted test data) and
- reproducibility

As a result of the compromise, refractive index is selected as the property to correlate with the specified product.

It is also important to obtain the best possible location for the sample take-off point along the process (tray level in fractionator). Tests plots of refractive-index change at various trays vs. a manipulated variable (reflux ratio) will indicate a tray level where the slope of the plot is greatest. Choice of this tray level assures the greatest overall control system sensitivity.

Confidence, with caution

Installations of analysis instruments already exist in plants and yield significant economic benefits. They are there because of the faith and perseverance in advanced analysis techniques of far-thinking engineers, plant managers, and chemists. At first extreme difficulties stood in the way of obtaining these benefits. Sometimes the equipment was not available and had to be developed, sometimes the equipment was available but was unreliable and hard to repair and keep running, and sometimes equipment cost was so high that it often precluded their use.

Over the years these difficulties have diminished. They still prevail for the many newer types just being introduced for plant use. Despite these difficulties, however, increased use of analysis instruments for composition analysis and their increased use in closed-loop process control can be logically predicted.

Additional articles on specific techniques will explain basics, show where each analyzer can be used, point out pitfalls, and—by shedding light on a complicated field of engineering—may speed the successful application of analysis instruments.

REFERENCE

1. *DESIGN CONSIDERATIONS OF SAMPLING SYSTEMS FOR PLANT STREAM ANALYZERS.* E. A. Houser, "Proceedings of Ninth Annual Symposium on Process Fluid Analyzers", N. J. Section, ISA, April 2, 1957.

Is It Less Expensive to:
Improve Controllers or Increase Safety Margins?

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THE GIST: In multiple control systems (such as heat exchanger systems in which both temperature and pressure controls affect the minimum coolant flow rate), a sufficient safety margin must be established for the dependent variable (flow rate). This margin keeps the system safe under the condition of maximum composite error due to the independent errors in each of the control systems. The safety margin (an increase in coolant, for example), is determined largely by the quality of the instrument-controller systems, so that a balance must be found between the costs of improving the control systems and increasing the safety margin.

In practice, design margins for multiple control systems have often been substantially higher than necessary, principally to insure against unknown factors. This article presents a procedure, based on the probability theory, for mathematically determining the safety margins needed for a given set of instrument-controller systems. Costs of improving the controllers or increasing the nominal value of the dependent variable can then be compared. An example is worked out in which the dependent variable is the coolant (pressurized water) flow rate in a nuclear power plant.

In multiple control systems, where there are several instrument-controller systems, there is often a process variable whose minimum value depends upon the independent errors of each of the controllers. In such systems, a sufficient safety margin must be established to make the dependent variable large enough to compensate for the maximum effective error due to the independent errors in each of the control systems. The system can then be designed to provide this minimum safe value.

Each instrument-controller system must have a small dead band; i.e., the controllers cannot be sensitive to errors smaller than those for which they can correct, or they might actually increase the errors. Thus, the various parameters of practical systems oscillate within small limits without resulting in any action by the controllers. Decreasing these dead bands requires, generally, an increase in quality, hence cost, of the instrument-controller systems. Increasing the dead bands, on the other hand, requires an increase in the minimum safe value of the dependent variable, which may be more or less costly. An engineering solution before the fact can be found by applying the theory of probabilities.

Controller error distribution

Before the probability can be found that a given value of composite error will occur in the dependent variable, it is necessary to determine the distribution of errors for a single controller system during its lifetime. It is reasonable to assume that the probability distribution of instrument-controller error follows a bell-shaped curve, as in Figure 1.

In the figure, E is the error in control or measurement, and $\phi(E')$ is the "probability density" at E equals E'. Thus, $\phi(E')dE'$ is the probability that $E' \leqq E \leqq E'+dE'$, and the area under the curve is unity, indicating that $-E_{max} \leqq E \leqq +E_{max}$.

Established error distribution curves are not available, but they can be approximated. Conservative approximations assume error distribution curves in

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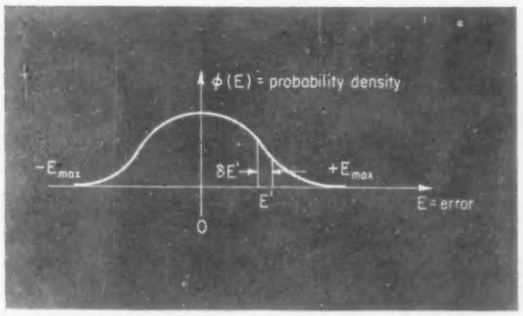


FIG. 1. Probability density of error for an instrument controller system has bell-shaped curve.

the form of trapezoidal or near-trapezoidal curves having bands of equal error probability and decreasing error probability, as in Figure 2. These curves are also assumed to include the effects of all detection, transduction, control-lag, etc., errors.

If $\alpha, \beta, \gamma, \delta, \ldots$, are used to denote the independent controlled variables to which the dependent variable F must be adjusted, and the abscissa is plotted as the percentage deviation from nominal F_N corresponding to a deviation in one of $\alpha, \beta, \gamma, \delta, \ldots$, then the ordinate is the probability density corresponding to this deviation.

The following assumptions must be made:

- The error limits are as stated. Actually, these limits may be only reasonable values subject to revision as more field experience is obtained and design and maintenance procedures are improved.
- The control systems fluctuate independently of each other within the limits indicated; the percentage change in the dependent variable needed to compensate for a certain percentage error in one independent variable is independent of the percentage errors in the other variables.
- All control systems are in service all the time; i.e., all control systems operate simultaneously.
- All conditions apply to steady-state operation.

Composite system safety factor calculation

Let $\overline{F}$ denote the "normalized" dependent variable F/F_N. Under the stated assumptions,

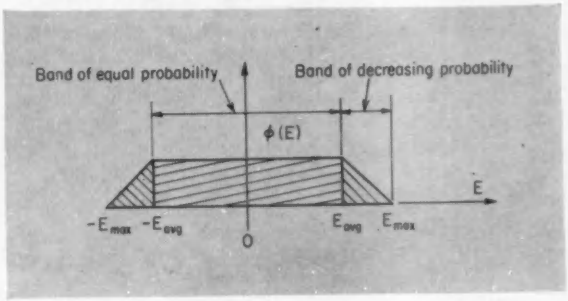
$$F = A(\alpha)\ B(\beta)\ C(\gamma)\ D(\delta)\ \ldots$$

where A, B, C, D, ..., are the fractions of $\overline{F}$ which correspond to errors in $\alpha, \beta, \gamma, \delta, \ldots$. A equals unity for zero error in α, B equals unity for zero error in β, etc.

If F_D is the design value of the dependent variable, it must be sufficiently larger than F_N to account for the composite effect of errors in $\alpha, \beta, \gamma, \delta, \ldots$. Thus, if A_{max}, B_{max}, C_{max}, D_{max}, ..., are the maximum fractional increases in F due respectively to errors in $\alpha, \beta, \gamma, \delta, \ldots$, then the safety factor of F_D/F_N might take one of the following forms:

1. $F_D/F_N = 1 + A_{max} + B_{max} + C_{max} + D_{max} + \cdots$

FIG. 2. Trapezoidal approximation of curve of Figure 1.



2. $F_D/F_N = (1 + A_{max})(1 + B_{max})(1 + C_{max})(1 + D_{max}) \cdots$
3. $F_D/F_N = 1 + D_{max}$, if D is the biggest of $A, B, C, D, \cdots$
4. $F_D/F_N = 1 + \sqrt{A_{max}^2 + B_{max}^2 + C_{max}^2 + D_{max}^2 + \cdots}$

Rigorous analysis

A rigorous mathematical analysis of the error in $\overline{F}$ is also possible. Now regard A, B, C, D, ..., as primary variables rather than $\alpha, \beta, \gamma, \delta, \ldots$. Then the way in which F varies as A, B, C, fluctuate independently can be determined if the ranges through which they fluctuate about their unity values are known.

It is more convenient in the analysis to take logarithms on both sides of

$$\overline{F} = A\,B\,C\,D\cdots$$

thus obtaining

$$f = a + b + c + d + \cdots$$

where $f = \ln \overline{F}$, $a = \ln A$, etc. The ranges of a, b, c, d, ..., are then:

Variable	"Normal Range"	"Extreme Range"
a	$0 \lessapprox \lvert a\rvert \lessapprox a_{avg}$	$\ln A_{avg} < \lvert a\rvert \lessapprox a_{max}$
b	$0 \lessapprox \lvert b\rvert \lessapprox b_{avg}$	$\ln B_{avg} < \lvert b\rvert \lessapprox b_{max}$
c	$0 \lessapprox \lvert c\rvert \lessapprox c_{avg}$	$\ln C_{avg} < \lvert c\rvert \lessapprox c_{max}$
etc.		

Trapezoidal probability distributions are assumed for a, b, c, d, ...; that is, all values of the quantity in the normal range are equally probable, and the probability falls linearly to zero through the "extreme" range (see Figure 3).

In the literature, $\phi_1(a)$ is called the "probability density function" for a. It shall be referred to here simply as the "distribution for a". The probability that

$$a' \lessapprox a \lessapprox a' + da \quad \text{is} \quad \phi_1(a')da$$

$$a' \lessapprox a \lessapprox a'' \quad \text{is} \quad \int_{a'}^{a''} \phi_1(a)da$$

$$a \lessapprox a' \quad \text{is} \quad \int_{-a_{max}}^{a'} \phi_1(a)da$$

$$-a_{max} \lessapprox a \lessapprox a_{max} \text{ is } \int_{-a_{max}}^{a_{max}} \phi_1(a)da = 2 \int_{0}^{a_{max}} \phi_1(a)da = 1$$

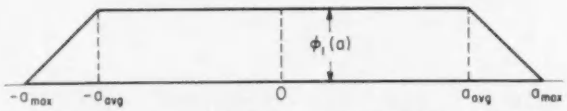


FIG. 3. Assumed trapezoidal distribution of a = 1nA, where A is fractional change in F for a change in controlled variable.

The last relation fixes the vertical scale in the plot of $\phi_1(a)$. A similar discussion holds for $\phi_2(b)$, $\phi_3(c)$, $\phi_4(d)$,... Knowing $\phi_1(a)$ and $\phi_2(b)$, the distribution for $p = a + b$ may be computed as follows:

$$\phi_{12}(p) = \int_{-a_{max}}^{a_{max}} \phi_1(a)\phi_2(p - a)da$$

Note that $\phi_{12}(p)$ is symmetrical about $p = 0$ if $\phi_1(a)$ and $\phi_2(b)$ each are symmetrical.

Likewise, the distribution for $q = c + d$ is:

$$\phi_{34}(q) = \int_{-c_{max}}^{c_{max}} \phi_3(c)\phi_4(q - c)dc$$

And finally, the distribution for $f = a + b + c + d = p + q$ is:

$$\phi(f) = \int_{-a_{max}-b_{max}}^{a_{max}+b_{max}} \phi_{12}(p)\phi_{34}(f - p)dp$$

Returning to the original variable, $\overline{F} = e^f$, the probability $P(\overline{F}_1, \overline{F}_2)$ that $\overline{F}_1 \gtrless \overline{F} \gtrless \overline{F}_2$ is the same as the probability that $f_1 \gtrless f \gtrless f_2$, where $f_1 = \ln \overline{F}_1$, etc. Thus,

$$P(\overline{F}_1, \overline{F}_2) = \int_{f_1}^{f_2} \phi(f)df$$

The next step is to define two cumulative distributions $L(F')$ and $G(F')$, which are those parts of $P(F)$ that are less than and greater than F', respectively. Remember that $\overline{F}$ is the ratio of the instantaneous value to the nominal value of the dependent variable, but F' is the particular ratio of the design value to the nominal value. $L(F')$, then, is the probability that $\overline{F} \gtrless F'$—i.e., that the instantaneous value does not exceed the design value. $L(F')$ can be calculated as follows:

$$\text{For } F' \gtrless 1, \quad L(F') = \int_{-\ln F'}^{F_{max}} \phi(f)df$$

$$\text{for } F' \lessgtr 1, \quad L(F') = \int_{0}^{\ln F'} \phi(f)df + 0.5$$

Within their limitations, these expressions, when plotted, indicate how much the design value of the dependent variable must exceed its nominal value.

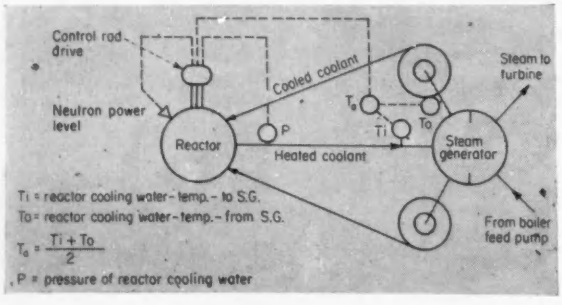
AN ILLUSTRATIVE EXAMPLE

Multiple control systems affect coolant flow in nuclear power plants

In a pressurized-water nuclear power plant, the heat from the reactor core passes across a metal-to-water interface to the reactor cooling water. The reactor cooling water flows to the steam generator where it gives up heat to convert lower pressure water to steam for use in a turbine. The cooling water at reduced temperature then goes back through the reactor. This system is shown in Figure 4.

It will be noted that there are three instrument-controller systems: temperature, pressure, and neutron power level. The temperature-control system is deliberately designed with a rather wide dead band because the reactor has a natural negative temperature coefficient which causes the neutron power level to decrease as the temperature rises. Outside this dead band, the temperature-control system acts to move the control rods.

FIG. 4. Pressurized-water nuclear power plant has several control systems which independently affect coolant flow rate.



The pressure-control system must keep the water pressure high enough to prevent the water from flashing to steam in the reactor core, which could result in warping or burnout of the core, and low enough to keep transient pressures from lifting the safety valves. The likelihood of flashing can be reduced by increasing the total coolant flow rate.

Because it is possible to operate steam plants at something over full rated power, it is necessary to limit the maximum steady-state power level of the reactor plant as determined by a neutron detector. Additional coolant flow must be provided to compensate for any error in the neutron detector.

Dead bands and possible instrument errors in each of these controller systems, then, require that coolant flow be increased above its nominal value (from the standpoint of reactor-core design) to make sure that sufficient coolant flows at all times to carry away the heat generated in the core. Still another variable requires that the coolant flow be increased. The main coolant pumps are driven by electric power systems whose frequencies may vary from nominal. Overdesign of coolant flow is determined by the amount the pumps' outputs may be affected by frequency changes.

To determine the margin in flow rate needed to compensate for instrument-controller errors, it is first necessary to describe the controller accuracy

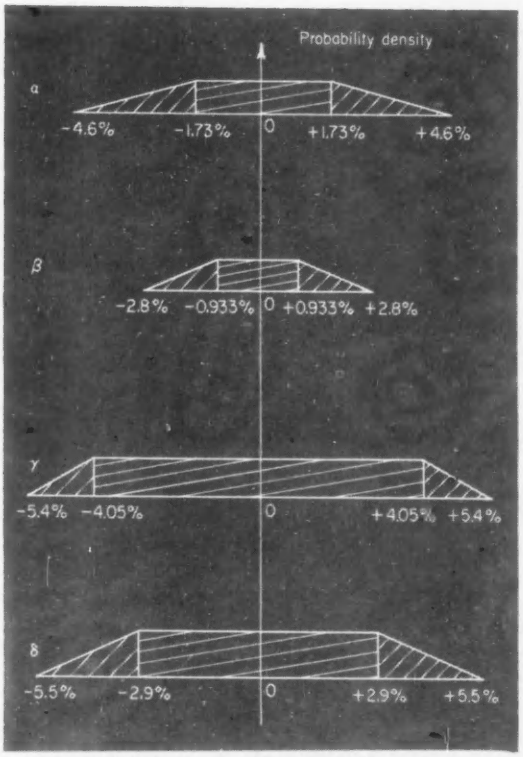


FIG. 5. Probability density distributions for errors in controlled variables in system of Figure 4.

available for the application. Table I represents the best available description of instrument-controller accuracies for the power-reactor application in point. α, β, γ, and δ henceforth denote the four independent controlled variables to which the coolant flow rate F must be adjusted. The information in Table I is presented graphically in Figure 5.

In the analysis, A, B, C, D are the fractional changes in F due to fluctuations in α, β, γ, δ, respectively; the ranges through which A, B, C, D fluctuate about their unity values are listed in Table II, which also lists the natural logarithms of these quantities.

A typical trapezoidal distribution for this system can be illustrated by the distribution for a: The probability that

$$-0.04497 \leqslant a \leqslant +0.04497$$

is

$$\int_{-0.04497}^{+0.04497} \phi_1(a)da = 1$$

The distribution for

$P = a + b$ is

$$\phi_{12}(p) = \int_{-0.04497}^{+0.04497} \phi_1(a)\phi_2(p-a)da$$

Finally, the distribution for

$f = a + b + c + d$ is

$$\phi(f) = \int_{-0.07259}^{+0.07259} \phi_{12}(p)\phi_{34}(f-p)dp$$

TABLE I

Nature of Instrument Error	Band of Equal Probability		Band of Declining Probability	
	Instrument Error %	Necessary Change in Flow %	Instrument Error %	Necessary Change in Flow %
α = reactor power	±3	±1.73	±8	±4.6
β = pump speed	±1	±0.933	±3	±2.8
γ = av. cooling water temp.	±1	±4.05	±3	±5.4
δ = cooling water pressure	±1	±2.9	±3	±5.5

TABLE II

Fluctuating Quantity	"Normal" Range	"Extreme" Range
A	$0.98270 \leqslant A \leqslant 1.01730$	$0.95400 \leqslant A < 0.98270$ $1.01730 < A \leqslant 1.04600$
B	$0.99067 \leqslant B \leqslant 1.00933$	$0.97200 \leqslant B < 0.99067$ $1.00933 < B \leqslant 1.02800$
C	$0.95950 \leqslant C \leqslant 1.04050$	$0.94600 \leqslant C < 0.95950$ $1.04050 < C \leqslant 1.05400$
D	$0.97100 \leqslant D \leqslant 1.02900$	$0.94500 \leqslant D < 0.97100$ $1.02900 < D \leqslant 1.05500$
F	$0.90701 \leqslant F \leqslant 1.09936$	$0.82897 \leqslant F < 0.90701$ $1.09936 < F \leqslant 1.19569$
a = ln A	$0 \leqslant \lvert a \rvert \leqslant 0.01715$	$0.01715 < \lvert a \rvert \leqslant 0.04497$
b = ln B	$0 \leqslant \lvert b \rvert \leqslant 0.00928$	$0.00928 < \lvert b \rvert \leqslant 0.02762$
c = ln C	$0 \leqslant \lvert c \rvert \leqslant 0.03970$	$0.03970 < \lvert c \rvert \leqslant 0.05259$
d = ln D	$0 \leqslant \lvert d \rvert \leqslant 0.02859$	$0.02859 < \lvert d \rvert \leqslant 0.05354$
f = ln F	$0 \leqslant \lvert f \rvert \leqslant 0.09472$	$0.09472 < \lvert f \rvert \leqslant 0.17872$

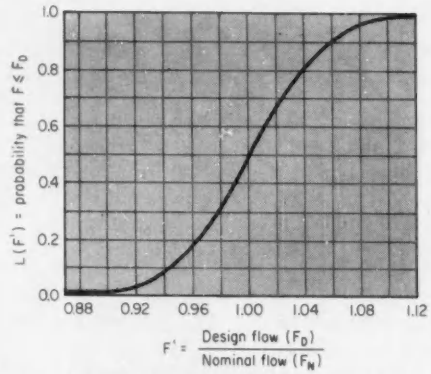


FIG. 6. Probability that instantaneous flow F needed to prevent burnout is less than design flow F_D, vs. ratio F′ of design to nominal flow.

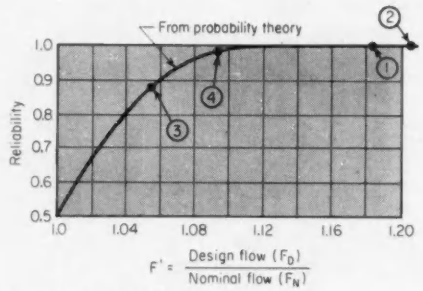


FIG. 7. "Reliability" of flow vs. F′.

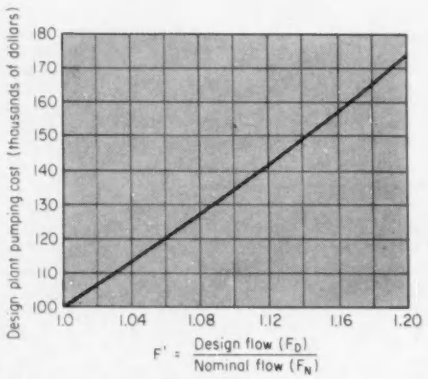


FIG. 8. Plant pumping cost vs. F′.

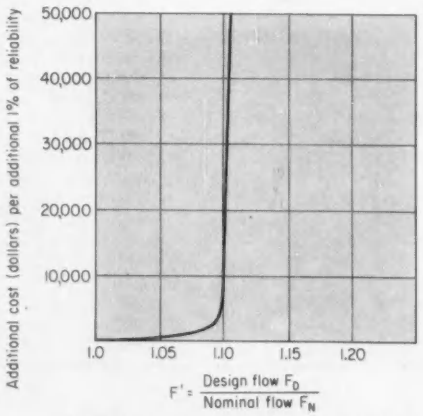


FIG. 9. Additional cost of pumping per additional 1 percent reliability, vs. F′.

The cumulative distributions $L(F')$ and $G(F')$ are:

for $F' \geq 1$,

$$L(F') = \int_{-\ln F'}^{+0.17872} \phi(f)df$$

and for $F' \leq 1$,

$$L(F') = \int_{0}^{\ln F'} \phi(f)df + 0.5$$

The last two equations are plotted against F' in Figure 6, which is the probability that the instantaneous flow rate required does not exceed F' F_N. Thus, if $F'=F_D/F_N=1.1$ there is less than one chance in 100 that the flow rate required at a particular instant will exceed the design flow rate F_D.

Application of analysis to plant design

The curve of Figure 6 can help in determining a reliable but economical plant design. First, the reliability of a particular design flow can be defined as the probability that the coolant flow at any instant does not exceed F_D. Simply replotting the right-hand half of Figure 6 then gives the curve of reliability vs. F', Figure 7. The four values of F_D/F_N obtained by the four criteria set forth originally are spotted on the curve in Figure 7. It can be seen that an excess flow of 12 percent is an optimum value. To design using criteria 4, 3 (square root of the sum of the maximum component errors squared; largest of maximum errors) produces too low a degree of reliability. To design using criteria 1, 2 (sum of maximum errors, product of maximum errors) wastes money without substantial improvement in reliability. Criterion 4, however, seems to be a good rule of thumb for rough estimates.

Figure 8 is a plot of pumping cost at one plant required to produce the various flows corresponding to F'. This cost will vary from plant to plant depending on the size of the pumps, the procedure for capitalizing electric power, etc. However, the reference cost, \$100,000 at $F'=1$, is realistic.

Figure 9 is a plot of additional cost per additional one percent reliability. That is, for each value of F' the slope of the cost curve (Figure 8) was divided by the slope of the reliability curve (Figure 7) and the ratio was plotted against F'. It is clear from Figure 6 and 9 that there is a point at which an increase in F' increases reliability very little, and that to increase F' beyond this point is to increase the cost of the plant greatly while increasing the reliability only slightly.

Note that the statements made here concerning "reliability" depend on the assumptions stated earlier; i.e., the possibility of failure of the instruments is not considered.

By the methods described, it is possible to study how money should be divided between providing excess pumping power and buying better instruments and controllers. Such a study can be made by repeating the calculations above for each price range of instrument-controller systems and then comparing.

RELIABILITY OF REDUNDANT SWITCHES

OBERT B. MOAN
Missile Systems Div.,
Lockheed Aircraft Corp.

This set of charts for your data file applies to systems that include decision-switching devices. Figure 1 treats the case in which a decision device automatically switches in a circuit to replace a faulty one. Figures 2 through 6 apply to a general class of systems whose functions are discrete in time.

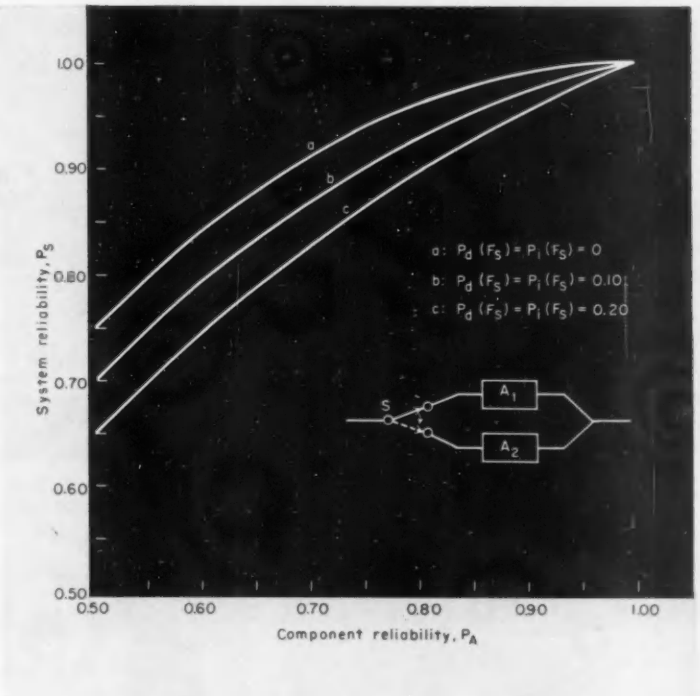


FIG. 1. Relationship of system reliability to component reliability in a parallel system using a decision-switching device.

OPERATION: *If A_1 fails, S will sense the failure and switch to A_2 where it becomes latched; i.e., S cannot return to A_1.*

CONDITIONS: 1. A_1 fails, A_2 succeeds
2. A_1 succeeds, A_2 fails
3. A_1 fails, A_2 fails

$P_d(F_S)$ = Probability that A_1 having failed, S fails to switch to A_2
$P_i(F_S)$ = Probability that A_1 having not failed, S switches to A_2

ASSUMPTION: $P_d(F_S) = P_i(F_S)$

DEFINITIONS FOR FIGURES 2 THROUGH 6:

p = probability that component will function upon command (direct).
q = probability that component will not function upon command (direct).
p' = probability that component will not function in the absence of command (inverse).
q' = probability that component will function in the absence of command (inverse).

Thus $p + q = 1$ and $p' + q' = 1$

COMMENTS:

1. Paralleling subsystems or components increases direct reliability.
2. Arranging subsystems and components in series increases inverse system reliability.

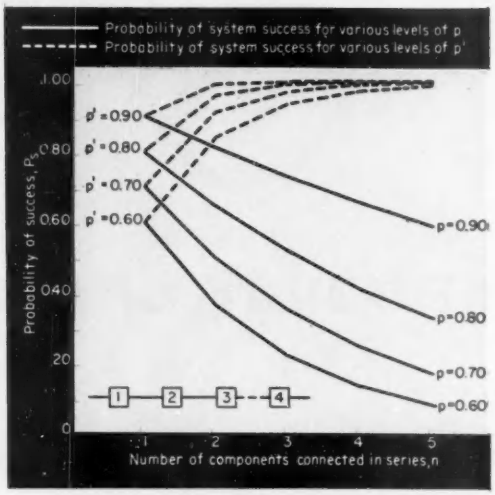


FIG. 2. Probability of system success as a function of the number of components linked in series.

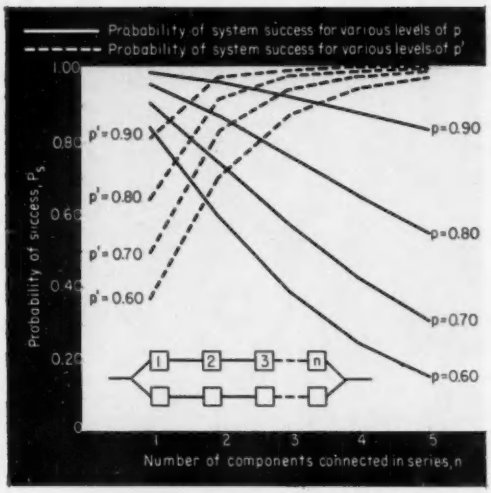


FIG. 3. Probability of system success for components linked in series when two series links are used redundantly.

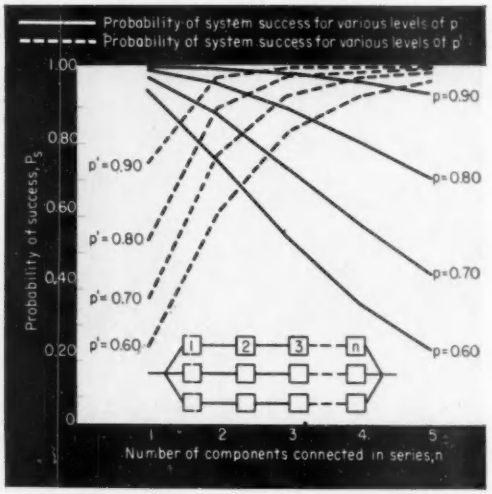


FIG. 4. Probability of system success for components connected in series when three series are used redundantly.

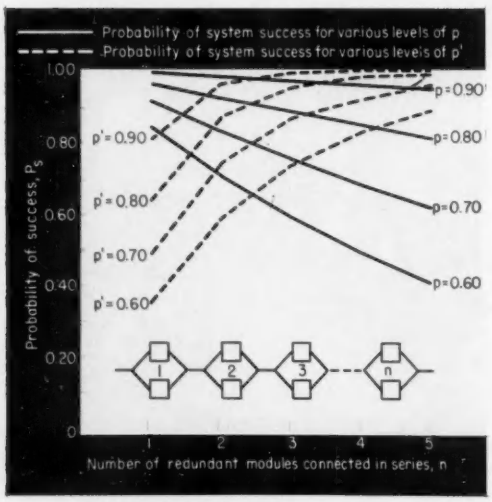


FIG. 5. Probability of system success for n redundant modules connected in series.

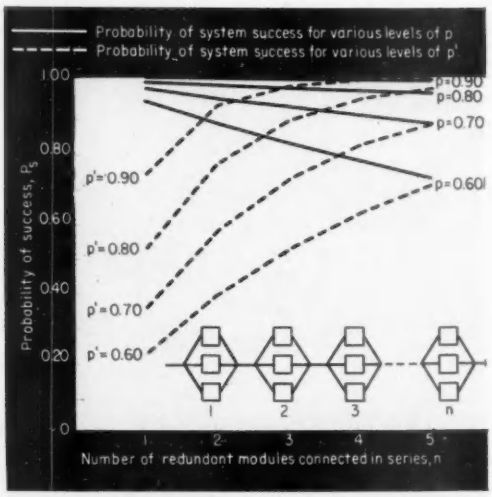
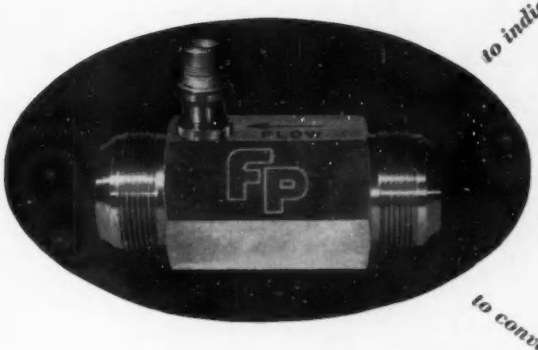
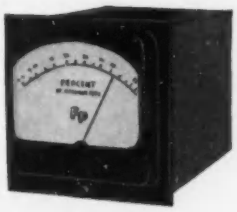


FIG. 6. Probability of system success for n triple-redundant modules in series.





PANEL FLOW RATE INDICATOR

to indicate flow

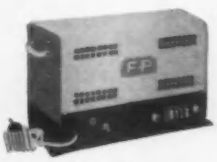
to indicate steady state flow condition

IN-LINE DIGITAL INDICATOR

to totalize flow for batch processes

DIGITAL TOTALIZER

to convert transient flow for analog output



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FREQUENCY MULTIPLIER-CONVERTER: Extremely rapid response to transient flow signals. Sampling of eight points per cycle provides more information than conventional means.

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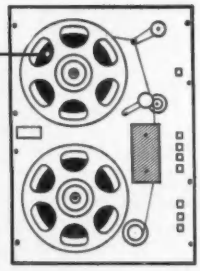
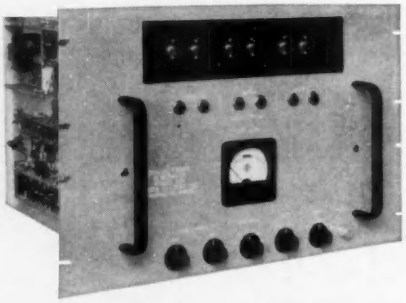




Two companion units by Hycon Eastern provide automatic high-speed access to selected data in Ampex Recorders and similar multi-channel magnetic tape instrumentation systems.

For Tape Indexing

DIGITAL TIMING GENERATOR, Model 201, generates numerically coded timing signals which are recorded on the magnetic tape throughout the data recording periods, providing a precise digital index in terms of elapsed time. The Generator also visually displays the exact time in hours, minutes and seconds as illuminated digits.

DESIGN FEATURES

TIMING INFORMATION occupies only a part of the available bandwidth on a magnetic tape channel . . . remaining bandwidth in timing channel may be used for other purposes; e.g. to record other digital or analog data, or as a voice channel.

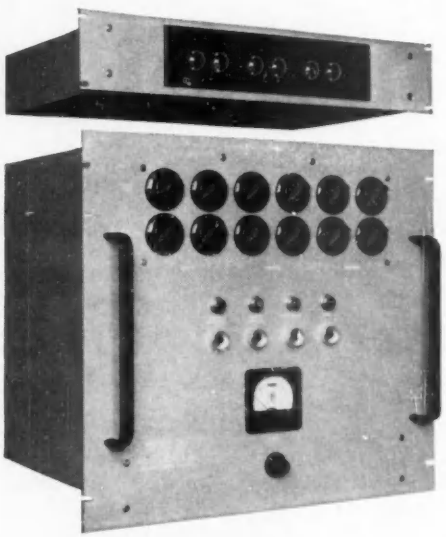
TAPE SPEEDS of 60, 30, 15, 7½, 3¾ or 1⅞ inches per second may be used for recording. For playback, any one of these 6 speeds or a high-speed search rate may be used. Other speeds may be incorporated as required.

TIMING TRACK contains a combination of complete time numbers in hours, minutes, and seconds together with interpolation pulses so that time can be measured with a resolution of a few milliseconds.

ADDITIONAL SIGNALS for recording, recovery and display may be assigned to arbitrary control functions in the data system.

FORWARD OR REVERSE directions may be used for tape search at either the high-speed search rate or any one of the 6 normal record play back speeds.

MOUNTS in any RETMA standard 19" relay rack.



For Tape Search

MAGNETIC TAPE SEARCH UNIT, Model 202, operates during data reduction periods. On the basis of time indices recorded on the tape by the Digital Timing Generator, this instrument automatically locates and selects for controlled playback the tape data included between a "sequence start time" and a "sequence end time" specified by panel dial settings. The time index is visually displayed as illuminated digits on a small separate panel which may be remotely located for convenience.

Write for Technical Bulletin TSG-J

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Magnetic Tape Indexing and Search Units
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Checking Techniques for Digital Computers

THE GIST: Computers get faster and faster. Machines that do basic arithmetic operations in a millisecond are commonly available, and 10-microsecond-per-operation machines are not far off. These machines, however, make occasional errors, and to make the maximum use of these speeds, they must be able to detect their own errors, decide what is the right answer at that stage of the problem, and proceed to a correct problem solution. They must also be able to indicate to the maintenance man where an error occurred, or else his task is nearly hopeless in the face of the machine's complexity. The principle of redundancy in checking, some error detecting codes, and a less-well-known error-detecting-and-correcting code are described.

The problems of human errors in coding and programming are little understood, and the automatic coding techniques and synthetic languages so far developed to lessen these problems have favored the machine over the human. Work to reduce this important source of errors brings the computer art full circle, because the logical conception of machine language must be studied. Humans cannot work without error in the nonredundant languages of present-day machines.

R. W. HAMMING, Bell Telephone Laboratories

Three sources of errors plague the user of a large-scale digital computer: machine operation, coding, and conception. The first two sources have been studied extensively, and this article traces only briefly what we have done to cope with these troubles. The third source of errors, misconception on the part of the problem proposer, is at present probably the greatest cause of wasted machine capacity; yet very little is known about it, except that it occurs much oftener than we wish it did.

This article tries to summarize past experiences in handling errors, and to describe a philosophy—the philosophy of using redundancy to check—that is consistent with what has been observed so far in the case of the first two types of errors. It is left to the reader to try his hand at applying this philosophy to the third source of errors, the humans who propose the problems.

The usual first approach to the problem of checking is to do everything twice and compare the results. For example, to check a particular computation for the presence of a machine error, the problem is run a second time and the answers to the two runs are compared. To make a reliable machine, duplicate equipment, say duplicate arithmetic units if they are the least reliable parts, may be built along with the necessary automatic comparing and checking circuits. And to check the preparation of a problem, two coders can be put to work independently on the problem of coding it for the machine.

Although the duplicate-effort approach has been widely used, it is very expensive and is seldom satisfactory in practice, and should be avoided.

Why is direct duplication usually not worthwhile? How does it work out in practice? First, there is implied in the approach of duplicate effort an independence of errors that is very seldom even remotely approached in practice. A machine develops a tendency to make a certain type of error in a certain circumstance only—the circumstance being exactly that which the particular problem causes at some particular stage. These intermittent failures are perhaps the most difficult to deal with of all those that may occur in a machine. Duplicate units, being usually on the same plan, leave much to be desired. Duplicate coding of a problem is very wasteful of the usually limited manpower, and, since the coders tend to eat lunch together, the independence is not what the supervisor thinks it is.

In the second place, a large problem

can be expected to produce more than one failure, so that quite likely duplicate runs or duplicate coding will merely produce two wrong answers, while the duplicate equipment may make twice as many machine errors (at least) as the single machine.

In the case of long problems, the duplicate method is usually modified to duplicate small parts of the problem, and then to check before going on; in sophisticated versions the machine itself runs the part, reruns it, compares the results, and only if the two runs check over that small part does the machine go on to the next piece[1].

The idea of redundancy is basic to all checking. Loosely speaking, redundancy means extra information over the minimum possible, or in some sense extra effort spent. Intuitively, with no extra information available there is no way of comparing the result with anything relevant so as to test accuracy or reliability.

Slightly more specifically, redundancy is measured by the ratio

$$\text{redundancy} = \frac{\text{extra effort}}{\text{total effort}}$$

In the case of duplication we have

$$\text{redundancy} = \frac{1}{1+1} = 1/2$$

Perhaps the most familiar examples of redundancy occur in the English language itself. It has been found by experiments that at least 60 percent of the normal English text can be removed and the meaning will remain; that is, English is at least 60 percent redundant. However, it should be noted that on occasions a single slip, or deletion, will radically change the meaning of the text, so that the language is not *uniformly* protected by redundancy. This fact is widely recognized; for example, in sending telegrams key words (or what are thought to be key words) are usually sent in duplicate at the end of the telegram.

DECIMAL	POSITION 0	1	2	4	7
0	0	0	0	1	1
1	1	1	0	0	0
2	1	0	1	0	0
3	0	1	1	0	0
4	1	0	0	1	0
5	0	1	0	1	0
6	0	0	1	1	0
7	1	0	0	0	1
8	0	1	0	0	1
9	0	0	1	0	1

FIG. 1. A two-out-of-five self-checking code, the so-called 01247 code. Note that each digit has two 1's, an error in any position producing other than two 1's and indicating an error in the computation.

Two opposing forces have acted on the evolution of language to fix the redundancy which is there. If the redundancy were less, humans could communicate more rapidly, but with a greater risk of being misunderstood. On the other hand, were the redundancy higher, communication would be more reliable, but the rate would be slower. It is reasonable to assume that the redundancy which has finally evolved is in some way related to the human nervous system and the normal modes of communication. This suggests a theme which will be taken up later, namely that the human animal is ill-equipped to deal with situations where the redundancy is low.

The purpose of machine checking is not merely to catch errors, but also to enable the maintenance to function properly. This often surprises those who are usually not involved in the maintenance. The maintenance staff *must* have ways of detecting and isolating machine troubles; it would be practically useless to tell them that a large computing machine was malfunctioning if they had no way of isolating the trouble.

Consider, as a further illustration, the modern telephone central office. Once a number is received, error detecting codes (to be discussed in a moment) are used throughout the various stages of switching that occur until the called line is actually rung, whether it be next door or across the nation. Now it happens that customer dialing errors greatly exceed central office failures; thus the error detecting codes do not directly decrease the number of wrong numbers called to any great extent, but indirectly, by enabling the maintenance staff to detect incipient troubles, they make the central office remarkably reliable. In this case, evidently, the extra equipment—the redundancy—is mainly there for maintenance. It is not greatly different, in fact, in computers, though the knowledge that if a number comes out of a computer it "must be right" is quite comforting to the user.

There are ways of making a machine self-checking without duplication of parts; it is not always necessary to do things twice to check on the accuracy of something. A simple illustration of this is the widely used "two out of five code" (one of a number of such codes, with no essential differences between them). In these codes there are five positions to be filled. Two of the positions are filled with 1's while the other three are filled with 0's. There are exactly $C(5,2) = 10$ ways this can be done, so that the ten decimal digits are conveniently represented in such a code. It is immediately apparent that a single error, either changing a 1 to a 0, or else a 0 to a 1, will leave an odd number of 1's in the group of five, while all correct messages have an even number of 1's; thus the error is detectable. This code has a redundancy of only $\frac{1}{5}$. Figure 1 illustrates the 01247 code—so-called because the sum of the two positions in which 1's appear represents the decimal digit. Other two-out-of-five codes can be constructed by simply allowing the codes to represent different decimal digits, e.g., 01236[2].

A very similar family of self-checking codes may be constructed as follows. Suppose there are n-1 binary digits of information to be sent, and that we add an nth digit, which is chosen so that there are an even number of 1's in the entire n positions. Just as above, a single error can be caught because there will be an odd number of 1's in that case. This is called a "parity" code. Here the redundancy is $1/n$. One can build circuits that compute in these codes, so that the machine can catch any single error when the information passes a check point. A double error, however, will escape detection and such codes may be used only if the density of errors is fairly low and errors in various positions are relatively independent of each other.

Another self-checking code that has seen a fair amount of use in practical machines is the so-called biquinary code, shown in Figure 2. It has two code groups of two and five bits each.

Error correcting codes

It is possible to go further in using redundancy and make a single error-correcting code. There is a great deal known about how to design such codes[3], as well as where to use the

DECIMAL	POSITION 5	0	4	3	2	1	0
0	0	1	0	0	0	0	1
1	0	1	0	0	0	1	0
2	0	1	0	0	1	0	0
3	0	1	0	1	0	0	0
4	0	1	1	0	0	0	0
5	1	0	0	0	0	0	1
6	1	0	0	0	0	1	0
7	1	0	0	0	1	0	0
8	1	0	0	1	0	0	0
9	1	0	1	0	0	0	0

FIG. 2. The biquinary code also has two 1's for each digit, and is thus self-checking. This code has been used on several practical machines.

various kinds, so it will suffice here to give a single example. In this particular code there are seven positions, numbered 1 through 7, to be filled with 1's or 0's. Take as the possible messages of information to be sent the 16 numbers, 0 through 15. In the binary system this set of numbers requires four binary digits, and these digits are placed in positions 3, 5, 6, and 7. The digit in position 1 (Figure 3) is chosen to make an even number of 1's in positions 1, 3, 5, and 7. Position 2 is set so that there are an even number of 1's in positions 2, 3, 6, and 7, while position 4 is set using positions 4, 5, 6, and 7.

Now consider any number, say 7, which is 0 1 1 1 in the binary code, and in the above code is

0 0 0 1 1 1 1

Now, to simulate an error, change one digit, says the fifth, from a 1 to a 0, thus

0 0 0 1 0 1 1.

Now apply the three checks over the positions

check 1: 1 3 5 7
check 2: 2 3 6 7
check 3: 4 5 6 7

and write a 1 each time the check fails, that is, each time there is an odd number of 1's in the four positions being checked, and write a 0 each time there is an even number of 1's. Writing this down, from right to left, gives

1 0 1

which is the binary representation of the number 5, the position in which the error was introduced! This works for every position, with all 0's meaning, of course, no error. Thus the position of the error is known, and hence the error can be corrected.

A single error-correcting as well as double error-detecting code can be made by adding an eighth position with the digit chosen to make an even number of 1's in the entire eight positions. It is left to the reader to see how this works in detail, since the main purpose of these examples is to show that error detection and correction need not require multiple efforts.

Coding redundancy for catching machine errors

Besides catching errors in the machine, extra coding can also be used to check a computation. One of the simplest examples is that of finding a root of a polynomial. While the computation may be long and complex, substituting the supposed root in the polynomial to see if it fits is a simple matter. If the root fits, this checks not only the computation but also the coding of the process of finding the root itself.

The double-entry system of bookkeeping is another example of coding

	POSITION						
DECIMAL	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0
1	1	1	0	1	0	0	1
2	0	1	0	1	0	1	0
3	1	0	0	0	0	1	1
4	1	0	0	1	1	0	0
5	0	1	0	0	1	0	1
6	1	1	0	0	1	1	0
7	0	0	0	1	1	1	1
8	1	1	1	0	0	0	0
9	0	0	1	1	0	0	1
10	1	0	1	1	0	1	0
11	0	1	1	0	0	1	1
12	0	1	1	1	1	0	0
13	1	0	1	0	1	0	1
14	0	0	1	0	1	1	0
15	1	1	1	1	1	1	1

FIG. 3. A seven-position error-correcting code. In this code the four binary digits for the decimal numbers are listed in positions 3, 5, 6, and 7. The other positions are for partial-check digits.

the work so that a validity check is readily available.

To get error correction, one may code the machine to do a computation, store the result, compute it again, compare the two results, and if they are not the same go back to the beginning of that part of the computation and start again.

In all these cases the redundancy uses more machine time and capacity than would be necessary were there no machine errors to cope with. The three examples are in order of increasing redundancy. The first example, the lowest in redundancy and effort in coding, is unfortunately not very typical.

In the earliest stages of the evolution of large-scale digital computers, debugging made use of "test problems" to locate the errors. This soon passed on to "diagnostic routines", which are really test problems whose wrong answers point more or less directly to the failing component. This is using redundancy in time.

Marginal checking

Another machine check is marginal checking, which is simply the process of altering certain voltages (usually) of various parts of the computer, and then noting where the failures occur. This method is widely used and is based on the belief that incipient failures can be located if the voltage is too high or too low. The truth of this assumption depends partly on the design of the machine, partly on the way the marginal checking is actually applied, and partly on the kind of failure. Intermittent failures of some types are not easily caught this way, nor are some catastrophic failures[4].

There is a tendency when using these methods to ignore the fact that they are using redundancy in time, and that using say, a redundancy of $\frac{1}{2}$ continually means a loss of half the computing capacity, or, equivalently, the construction of a second machine just like the first one.

Coding redundancy for catching program errors

In checking the computation of a root of polynomial, the coding was checked, too. This situation also occurs in problems of solving ordinary differential equations. Milne's method, for example, "predicts" a new value for each variable, and then at the end of the cycle calculates the "correct value". If these agree within a certain amount, then

1. the computation was correct or the errors were sufficiently small as to be unimportant,
2. the coding of the two parts was consistent, and
3. the assumptions behind the method of integration are justified.

In special cases, the problem has known answers, and if on running these cases the answers check, then more faith can be placed in the correctness of the coding (although anyone who does this very long will soon have the unpleasant experience of having several special cases check perfectly with the coding seriously wrong). Degenerate cases, that is, cases where certain parts of the program are not used, also are quite useful when their solutions are known from other sources.

Automatic coding

All the above methods put the burden of checking on the human, who is already overloaded. As was observed earlier, humans appear to be ill-adapted to deal with nonredundant situations, such as coding for a computer in the language of microsyllables provided by the designers of most computers. Most machine codes were carefully designed to have no redundancy and to do one simple elementary step for each instruction. Worse than this, perhaps, the addresses where numbers and orders are stored in the machine usually have nothing to do with the problem and in many respects are nonsense syllables, with which, again, the human animal is ill-adapted to cope.

Even before computers were made reliable, there had been efforts to have the machines do part of their own coding. Once the machines were truly reliable, it was an obvious step to their

taking over most of the burden of coding. Let the human write out the problem in a language that is well-suited to himself, then give the machine a dictionary, and possibly a bit of grammar too, and let it translate from the human's language into machine language.

The process of letting the machine do the detailed coding is often called "automatic coding". It amounts to introducing a synthetic language for the human, along with a translation process for the machine, in converting the synthetic language into machine language. This is now widely done, and has been very satisfactory[6]. In one sense, it is producing reliable coding by putting the detailed coding process back on the machine which has, often by means of built-in redundancy, a high degree of reliability.

The next question is, "What are the characteristics of a good language of communication for a human to use when he is working with a computing machine?" Although the linguists have studied languages for a long time, it turns out that they have very little to say on this subject, and admitting that there is no real data, common sense must be resorted to. Some desirable properties would seem to be:

1. the language should be compact, in the sense that a few words in the language should produce a good deal of computing by the machine;
2. the language should avoid, as far as possible, the use of nonsense syllables, specifically references to the actual addresses where the numbers and orders happen to be stored for a particular problem, and
3. the language should have some redundancy so that it can be used comfortably by humans instead of requiring an almost impossible standard of perfection.

Without going into the detailed evolution, one may say that the field of automatic coding has progressed through items 1 and 2 above: the first by means of subroutines and synthetic languages, and the second by means of regional coding, symbolic coding, and nonaddressed coding systems. The latest efforts along these lines are to use the equations themselves as inputs to the machine, along with a few standard phrases to indicate the relationships between the equations.

One may say that these methods, while highly successful, have left the human in a situation where he has no usable redundancy to protect himself. How to get out of this situation is not at present very clear, but the philosophy expressed in this article suggests that if humans are to work with machines, then the language of communications should have some redundancy in it for the sake of the humans. This should be, ideally, a uniform redundancy which, unlike English, would give uniform protection against slips. Actually, the design of such a language should rest on a better understanding of the nature of the human slips and their causes than we now have.

In the beginning of this article, three sources of errors were listed, machine operation, coding, and conception, and it was remarked there that the third one ". . . is at present probably the greatest cause of wasted machine capacity . . ." The first has been covered by better engineering and when necessary, built-in redundancy. The second is fairly well under control when a good method of automatic coding is used, though a lot remains to be done. Almost nothing has been done on the third source of trouble, faulty conception and planning. This problem transcends machines, it is universal; but it is not necessarily impossiple to alleviate to some extent.

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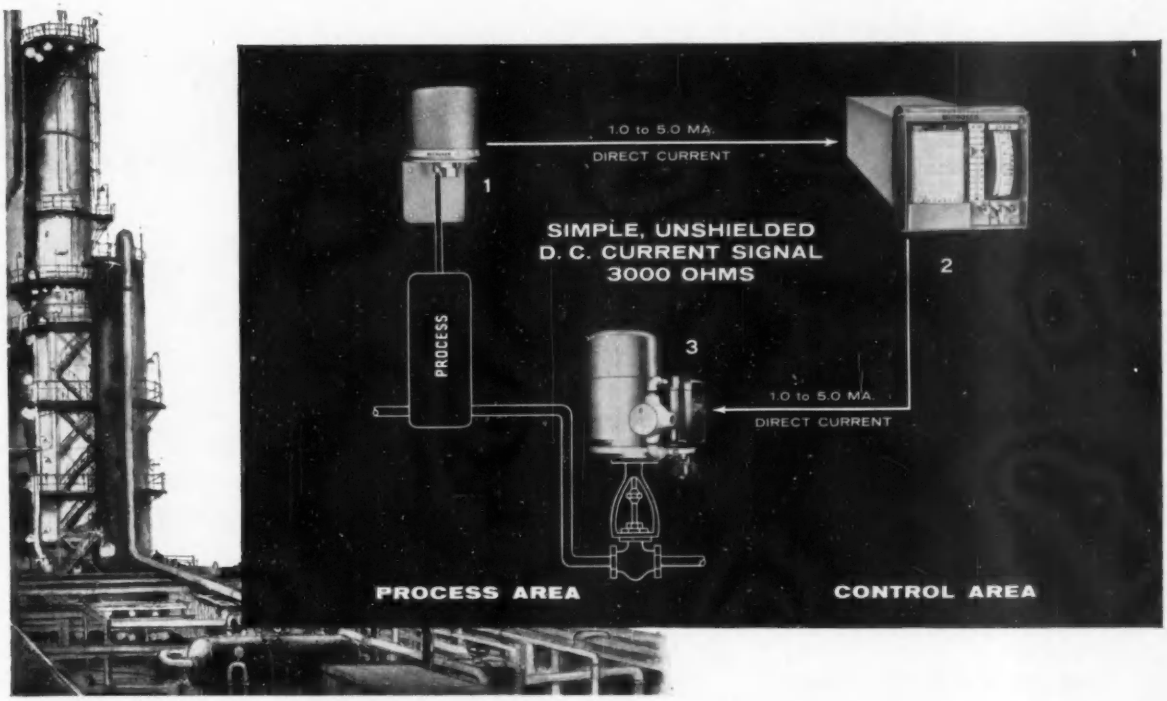
RICHARD W. HAMMING

Dr. Hamming came to Bell Telephone Laboratories in July 1946 as a mathematician with computer experience—quite a rare combination in those days. He was introduced to the automatic computer as a practical tool while working at Los Alamos on calculations incidental to the world's first atomic explosion. His interest, as a mathematician, in being sure that the machine produces the right answers has led him to contribute to some redesign work on BTL's analog computer. Before his Los Alamos days, Richard Hamming taught mathematics at the University of Illinois, where he received his PhD in math in 1942. He got his bachelor's degree from the University of Chicago in 1937, and his master's from the University of Nebraska in 1939. Dr. Hamming is vice-president of the Association for Computing Machinery.



Let's look at a typical control loop of the 'American-Microsen' *ELECTRONIC PROCESS CONTROL SYSTEM*

This all-electronic dc system of miniature-type units assures the instrument engineer of 1) better control; 2) greater flexibility; 3) lower initial costs; 4) lower operating costs. The typical control loop above demonstrates the simplicity and functions of the system.

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Transistorized design increases reliability and service life. Miniaturization and consolidation of control functions reduces panel cost and wiring expense.

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Where required, the American-Microsen Electro-Pneumatic Valve Positioner or the Electro-Pneumatic Transducer can be supplied.

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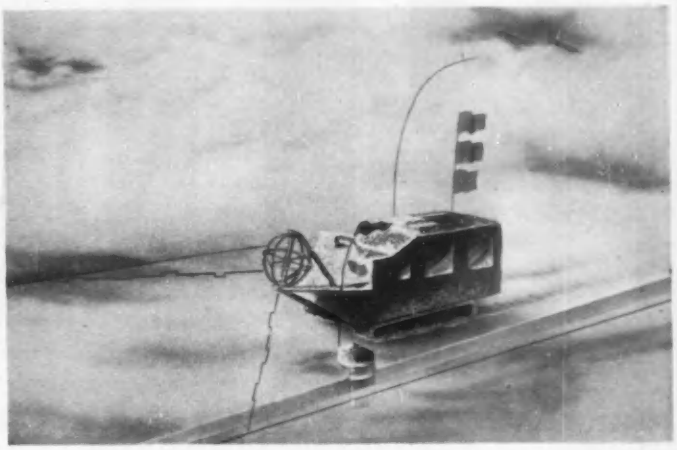
Electronic Trail-Finding

A "Weasel" moves safely in fog and blizzard along a trail marked by two wires buried 75 ft apart in snow. More than 100 miles at a time have been negotiated easily with the help of this magnetic navigation system.



CALVIN O. O'ROURKE
Engineer Research & Development Laboratories, Fort Belvoir, Va.

Poor visibility during snow storms, and summer "white-outs" (dense fog) makes free movement in the Arctic virtually impossible. Safe trails through dangerous, crevassed areas are crooked and narrow. Visual markers like flags and poles are useless, since they are obscured by poor visibility or destroyed by the elements.

The development of an electronic trail-marking system by the Engineer Research & Development Laboratories and General Mills, Inc., marks a giant stride against these hazards.

This system has been used to navigate more than half of a 220-mile electronic trail on the Greenland Ice Cap in white-outs, blizzards, and combinations of the two. In the first 42 miles, this trail crosses about 10 known crevasses varying in width from 2 to 30 ft and depths up to 75 ft.

The system consists of the terminal gear, the wire trail and accessories, and the vehicular equipment.

The terminal gear supplies a 60-cps ac on two wires buried in the snow and ice for the length of the trail. These wires are buried on each side of the trail 75 ft apart and at depths of from 2 to 20 ft under the snow, and are shorted together at the far end to complete a long loop. The power transformer is provided with taps from 150- to 1,600-vac to allow use on trail systems covering from 20 to 300 miles. The tap selected is one which would provide a minimum of 1 amp on a specified length trail system. It was found during tests that the maximum required to navigate a 120-mile system was 300 volts at ½ amp.

The secondary of the power transformer is connected to a 60-cps resonant circuit in series with the trail wires. This resonant circuit is used as a coupling circuit to allow insertion of audio communication and dc alarm circuits to the trail wires. A 30-ma dc current in the trail wire, which continuously energizes a relay at the terminal gear, gives visual and audible indication of broken trail wires. When the wire is broken, the dc current drops to zero and the relay is de-energized, operating a bell and light.

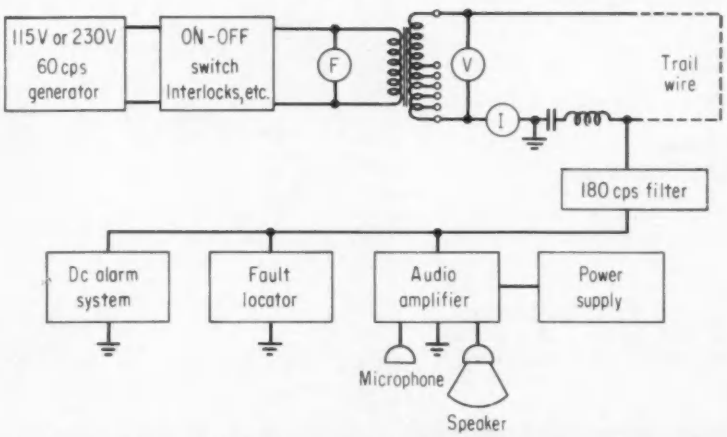


FIG. 1. Terminal equipment like this need be located at only one end of trail.

Three-loop antenna

Vehicular equipment consists of an antenna assembly, an electronics receiver, a control panel, and a dynamotor power supply which operates from 12 or 24 volts dc. The receiver amplifies the antenna voltage, computes the heading and position of the vehicle relative to the trail, and initiates the out-of-trail and loss-of-signal alarm. The receiver and antenna working together present to the driver by visual indications on the control unit his position on the trail during zero visibility weather.

Three mutually perpendicular loops mounted rigidly ahead of the vehicle and forming a spherical configuration comprise the antenna assembly. Each

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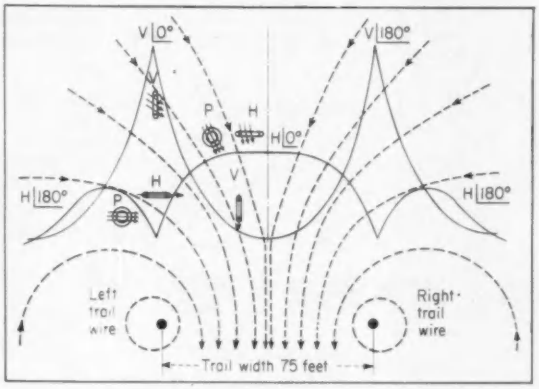

FIG. 2. Magnetic field around two wires, with induced voltages in horizontal loop H and vertical loop V superimposed.

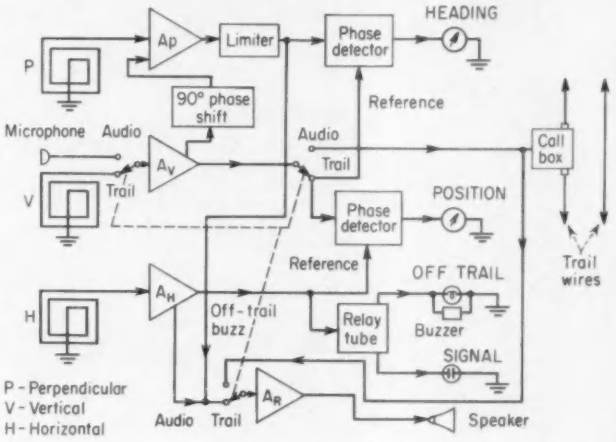

FIG. 3. Vehicle carries this receiving equipment.

loop is about 32 in. in diam and contains approximately 4,200 turns of AWG No. 34 copper wire, or about 3.5 miles of wire per loop. These are identified in Figure 2 as the horizontal (H), verticle (V), and perpendicular (P) antenna loops. Figure 2 shows the magnetic field, and the voltages that induces in the vertical and horizontal antennas when the vehicle is parallel with the trail wires.

The horizontal signal is used as a reference for the position meter, since its phase is constant between the two trail wires. The vertical antenna signal is compared to the horizontal reference in the phase detector. As shown in Figure 2, the magnitude of the vertical signal is roughly proportional to the position of the vehicle from the center of the trail, and the phase detector converts this signal to a dc meter current. The relative phase between the vertical and horizontal signal defines the meter's dc polarity.

The horizontal signal is also used to operate an out-of-trail warning light by de-energizing an alarm relay when the horizontal signal approaches zero.

A third use of the horizontal signal is as a receiver of the audio communication signal in the trail wires through the antenna while the vehicle is moving. A 500-cps high-pass filter in the input of the audio amplifier reduces the strong 60-cps signal present in the horizontal loop.

The vertical and perpendicular signals give heading information. The perpendicular signal is obtained from an antenna loop in a plane perpendicular to the direction of motion of the vehicle. When the vehicle is moving parallel with the trail wires, no voltage is induced in this loop. A circuit is used to shift the vertical signal by 90 deg and add it to the perpendicular signal with the resultant signal being amplified and its magnitude limited to about ½ volt. The only variable left in the signal is the phase angle. The limited signal is fed into a phase detector that has the original vertical signal as a reference. The output of the phase detector is a function of the heading angle (phase of resultant voltage) and is displayed as left or right heading information.

Work is continuing to improve existing techniques and equipment. A one-wire trail-marking system, which may reduce installation and maintenance costs, is under consideration.

Pulse Response to Frequency Response —Mechanically

Lt. Cmdr. M. T. GARDNER, Royal Canadian Navy

Here's a predominantly mechanical way to get FR data by disturbing a system only once with a short-duration pulse. The input pulse and the system's response are recorded simultaneously. Then the recording is analyzed by the device described here to get amplitude and phase vs. frequency data.

Commercial frequency-response analyzers generally require discrete sinusoidal inputs to the system under test; that is, the system must be subjected to as many different frequencies as are necessary to plot its response over the frequency range of interest. This method is not only time-consuming, since it involves the system itself at each step of the test, but it also subjects the system to unnecessary wear, especially at the higher test frequencies. It may be impractical, too, for, as in the case of determining the frequency response of large chemical plants, the cost of waste products that would be produced during such a test is prohibitive.

The pulse method of frequency-response analysis has been used for some time in the aircraft industry[4], and numerical and graphical methods of reducing the data are discussed in the literature[1,2]. At least one electromechanical analyzer has been described that automatically produces the frequency response of a system from a recording of its response to a

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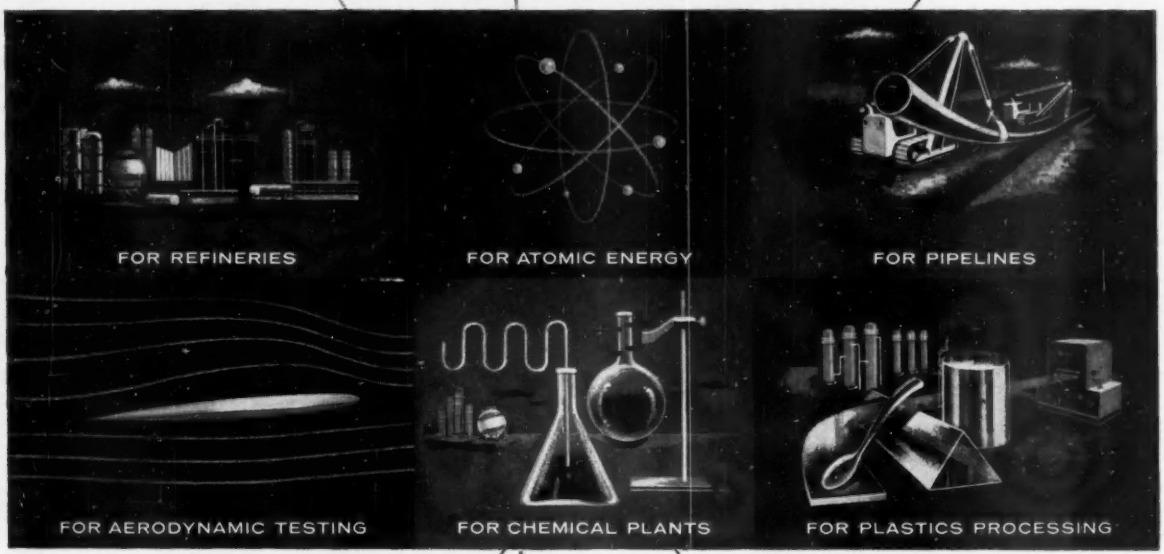

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single pulse[5]. This article proposes a basically mechanical analyzer that will give the same results.

Theoretical basis

The analyzer is based on the fact that the Laplace transform provides a means for converting time-dependent functions to frequency-dependent functions; i.e.:

$$F(\omega) = \int_0^\infty F(t)\, e^{-j\omega t} dt$$

where $F(\omega)$ is a frequency dependent function and $F(t)$ is a time dependent function which is zero for $t<0$. The sinusoidal frequency response of a system may thus be defined as

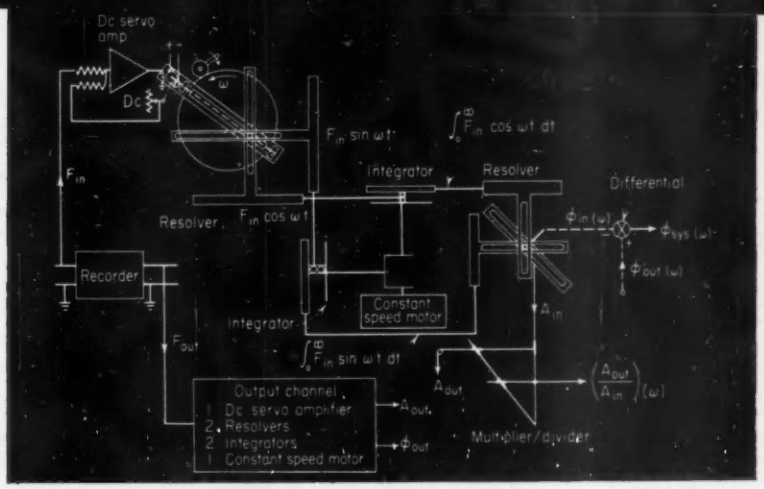
$$FR_{sys} = \frac{\int_0^\infty F_{out}(t)\, e^{-j\omega t} dt}{\int_0^\infty F_{in}(t)\, e^{-j\omega t} dt}$$

which may be written

$$FR_{sys} = \frac{\int_0^\infty F_{out}(t)\cos\omega t\, dt - j\int_0^\infty F_{out}(t)\sin\omega t\, dt}{\int_0^\infty F_{in}(t)\cos\omega t\, dt - j\int_0^\infty F_{in}(t)\sin\omega t\, dt}$$

The mechanical analyzer diagrammed in Figure 1 is a mechanization of this last equation. The numerator is equal to $A_{out}(\omega)$ at an angle of $\phi_{out}(\omega)$. The denominator contains the same amplitude and phase information about that particular frequency (ω) component in the input pulse. The division of the output terms by the input terms thus represents the amplitude ratio and relative phase angle of the system being analyzed at the frequency ω.

Note that two identical mechanical analog computers are required to simultaneously solve the terms in the numerator and denominator. The recorder and the mechanical divider are common to both computers. The recorder reproduces a voltage analog of both the input test pulse and the system's response to it, simultaneously. The test frequency for which the response is to be found on the analyzer is entered at the first resolver.



Mechanical dynamic analyzer is based on the Laplace transform, which converts time functions to frequency functions.

The first resolver has a slotted bar mounted on a gear that is driven at the test frequency. The slot guides a pin on a traveling nut that follows a lead screw. The pin is servo-positioned, by means of the lead screw, at a distance from the gear center proportional to the input function. The outputs of the first resolver are the sine and cosine components of the ω-component of the input function. Each of these components is integrated against time and then transformed back to polar form by the second resolver. The output amplitude is then divided by the input amplitude to get the amplitude ratio of the system under test at the frequency ω. The phase angles are subtracted in a mechanical differential to obtain the phase lag due to the system under test at the frequency ω.

The test must be rerun for as many frequencies as are needed to plot the frequency response, but the system itself need be disturbed only once to record its response to an arbitrary input pulse of short duration. As with all frequency response measurements, the system under test must be assumed to be linear with respect to amplitude at any given frequency, and this requires that none of the frequency components in the pulse be large enough to drive the test system into saturation regions. Otherwise, the pulse shape is restricted only in that it must begin and end at zero amplitude.

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Thermistor Hot-Box Detector

Overheated journal boxes on freight cars can be detected on-the-fly and in spite of bad weather by the thermistor. Servo Corp. of America has an operating system that uses two thermistors in a bridge circuit. One thermistor sees the journal boxes; the other sees only ambient conditions to keep the bridge balanced for ambient temperatures from minus 25 to plus 130 deg. F. The flanges on the train's wheels disturb the field of a permanent magnet transducer, providing gating pulses that make the thermistor active only when a journal box is in its field of view. Thus, brake shoes and steam lines are not seen. The system produces a record like that across the top of these columns. A recorder pen deflection larger than four times a normal heat impulse is considered to be a hot box. The thermistor time constant is about 5 millisec; recording is reliable at 60 mph.

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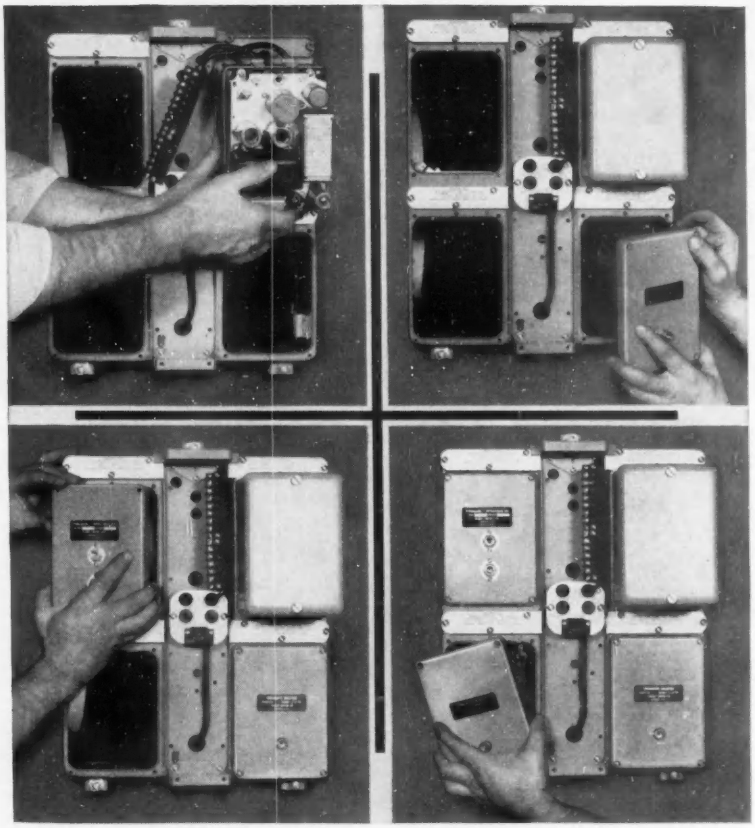

These four views of the back of a Bailey Recorder show how four plug-in units may be added as needed to meet almost any recorder application.

The freedom and flexibility of "do-it-yourself" instrumentation is yours in the Bailey Recorder. A variety of plug-in units make it possible to record, control, and retransmit any variable that can be converted to a pneumatic or electric signal.

The basic plug-in units are the Bailey a-c and d-c Electronic Receivers and Pneumatic Receivers. Any four of these may be used in one recorder, intermixed in any way, to provide four continuous records on one chart.

For automatic control, other plug-in units are available.

For square root extraction or linear integration, there are two plug-in variations of the Bailey Integrator.

When you want a pneumatic signal that varies according to a pre-set pattern plug in a Bailey Program Controller.

Periodic running time of a condition or process is recorded on the chart when a Bailey Running Time Recorder is used.

These and other plug-in units are described in Product Specification E12-5. Some companies stock Bailey Recorder cases and assorted plug-in units. As instrumentation and control needs arise they build up the kind of recorder-controller required, using the proper plug-in units from stock. Unmatched versatility such as this means lower instrumentation costs.

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Guided-missile components must withstand severe accelerations during launching of the missile. In order to test components under launching conditions, Northrop Aircraft Co.'s Engineering Laboratory designed and built an air-powered test sled, which is, in effect, a giant sling-shot. The sled is unique in that acceleration buildup is controlled to a sinusoidal waveform, rising to any desired peak value between 4 and 8 g's. Acceleration at the peak value is then sustained to a total elapsed time, including acceleration buildup, of at least 0.25 sec.

The test sled, designed specifically to test components for the SM-62 (Snark) missile, had to conform to a specified program of accelerations. A test "run" divides into six phases:

1. Acceleration buildup, a controlled sinusoid—reaches a peak variable between 4 and 8 g's at a time variable from 0.040 sec to 0.140 sec after "firing".
2. Acceleration at the phase 1 peak value—sustained to a total elapsed time (including phase 1) of at least 0.25 sec.
3. Acceleration decay—controlled to provide a lower rate-of-change of acceleration than during phase 1.
4. Deceleration buildup—uncontrolled, but providing a lower rate-of-change of acceleration than during phase 1.
5. Deceleration after buildup—sustained at one-half the acceleration of phase 2.
6. Deceleration decay—uncontrolled.

System description

Figure 1 is a drawing of the entire testing assembly. The test sled, shown at the middle, left, riding on the rails on top of the superstructure, is driven by cables attached to a free piston inside the long pneumatic cylinder that can be seen below the rails and within the superstructure. The cylinder itself is shown in Figure 2.

The rate of acceleration buildup and the peak acceleration are determined by adjusting the initial cavity at the head of the piston and the initial orifice. A quick-opening valve triggers the acceleration cycle, providing a constant pressure to the initial orifice at air flows from 0 to 10 lb/sec. Acceleration buildup conforms

FIG. 1. Side elevation of Northrop's controlled acceleration "sling-shot" for simulating accelerations that occur during missile launchings.

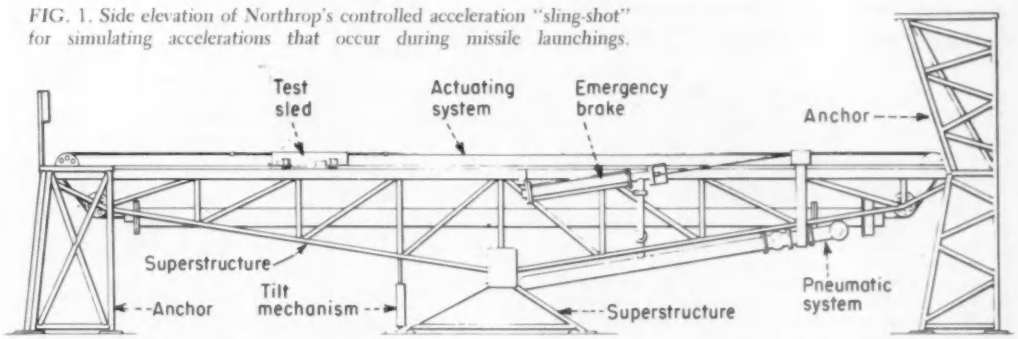
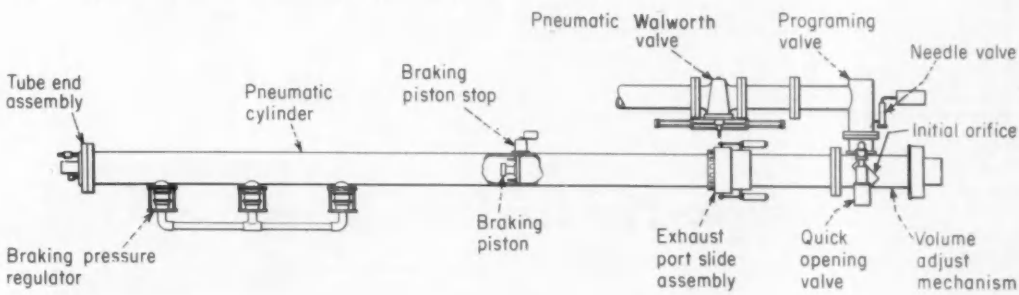


FIG. 2. Pneumatic control system for "sling-shot". Drive piston starts from right end, begins decelerating after it passes exhaust port.



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Eclipse-Pioneer Coded Commutator type shaft position-to-digital converters are miniature devices for converting Analog information to Binary Digital form. Designed for Digital control systems, data processing equipment, telemetering applications, or computers. Especially suited to air-borne use.

Specifications:

	Model GS-1-A1	Model GS-2-A1
Type output	8 digit gray (Reflected Binary Code)	7 digit Natural Binary Code (double brush)
Shaft resolution	1 part in 256	1 part in 128
Current rating	.015 amps. (max.) per digit with non-inductive loading	.015 amps. (max.) per digit with non-inductive loading
Shaft speed	Max. continuous input of 150 revs. per minute	Max. continuous input of 150 revs. per minute
Input torque	0.2 ounce-inch (max.)	0.4 ounce-inch (max.)
Diameter of unit	15/16 inch	15/16 inch

In buying precision synchros, doesn't it make a lot of sense to insist on getting exactly what you want, when you want it—and at minimum cost?

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Our mass synchro production facilities . . . the nation's largest . . . are constantly turning out just about all types of synchros imaginable. This means we can offer you immediate delivery of most synchro types—and minimum cost on all synchro types, even for small quantity orders.

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District Offices: Burbank, Calif., Dayton, Ohio, Seattle, Wash.
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Bendix
AVIATION CORPORATION

to the desired sinusoidal curve. Actuation of the quick-opening valve also starts a Berkeley counter, which triggers the programming valve at the top of the sinusoidal acceleration buildup to admit more air (up to 30 lb/sec) into the cylinder. The programming valve continues to open at a controlled rate to keep acceleration constant.

Braking is done by another free piston, which has in its center an air seal made of alternate layers of felt and leather liberally oiled, through which the driving cable passes freely. The braking piston is held at rest, by a preset braking pressure, against a one-way stop about half-way down the cylinder. As the driving piston passes the exhaust ports, pressure builds up between the driving piston and the braking piston and the braking piston begins to move. This technique permits pickup of the braking force without overshoot. A constant braking pressure is maintained during the deceleration phase by the braking pressure regulator.

Instrumentation

In a typical run, galvanometers trace braking pressure, driving pressure, and manifold pressure to quick opening valve, forward accelerometers, vertical accelerometers, and yaw accelerometers, and firing-switch impulse, programming-valve initial position and opening point, time-delay input to programming valve, and impulse from opening of the program valve switch.

Before firing, a technician checks excitation voltages to strain-gage transducers by turning a selector switch on a control panel and checking the meter-indicated voltages against a chart of predetermined values. Closing the firing switch starts a stepping relay which, in turn, starts the recording oscillograph, calibrates all strain-gage channels, and then "fires" the test sled. The Consolidated Electrodynamics recording oscillographs (Type 5-114) used are preset to run 55-in. long records at 19.2 in./sec. Figure 3 shows how transducer signals are led from the test sled to the recording oscillograph by means of flat cables picked up from a trough beneath the sled as it moves down the track.

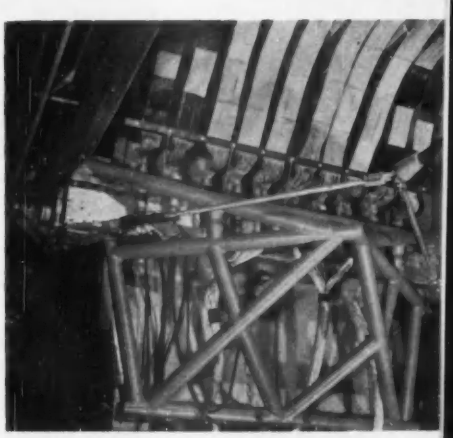
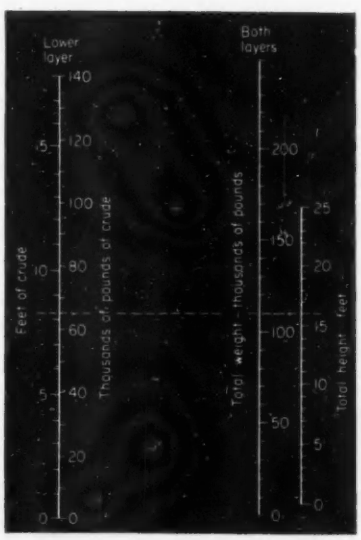


FIG. 3. View of test sled shows how transducer cabling is picked up from trough beneath sled during test run.

An Inexpensive Way to Measure Interface Level

J. P. SHOFFNER, E. I. du Pont de Nemours & Co., Inc.

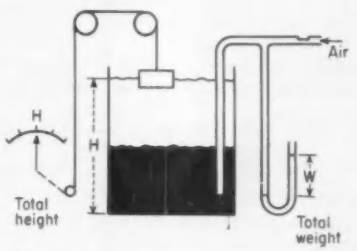
A problem in interface level measurement at du Pont's Sabine River Works was solved recently in a relatively simple and practical way with two basic level-measuring devices. The ultimate objective was to determine the pounds of lower layer material in a storage tank containing two immiscible liquids of different specific gravities.



A manometer with dip tubes extending vertically from the top of the tank had been used as a total material inventory measure, but it lacked the facility for accurately determining the amount of lower layer material present. A second instrument—a float-actuated-type level gage—was installed on the tank. It was then possible, using the manometer and float readings, to determine the interface level and, finally, the quantity in pounds of the lower layer.

The float gives a volumetric measurement of total amounts of liquid present. The dip tube, however, measures the difference in pressure between the top and bottom of the tank, which is proportional to the total weight of both liquids. With total volume, total weight, and density of each liquid known, the weight of each liquid is expressed by:

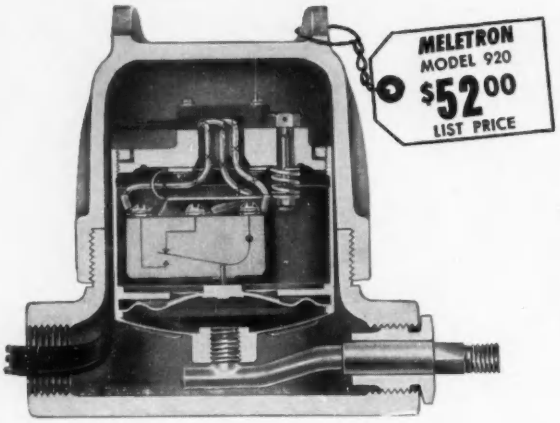
$$(d_2/d_1 - 1)W_1 = W - d_2AH \quad \text{(top layer)}$$
$$(1 - d_1/d_2)W_2 = W - d_1AH \quad \text{(lower layer)}$$



where A = tank area, ft²
d = liquid density, lb/ft³
H = liquid level, ft
W = liquid weight, lb

Subscripts 1 and 2 refer to upper and lower immiscible liquids, respectively.

The alignment chart shown applies to the particular tank size, instrument calibrations, and liquids encountered in the Sabine application. It proves a fast and easy method for the operator to determine the amount of the heavier liquid present. The amount of the top layer can then be found by difference. The red line shown gives the solution for readings of 16 ft total height and 110,000 lbs total weight. The lower portion will be seen to measure 8.3 ft and weight 66,000 lbs.



Here's the Simplest Diaphragm Pressure Switch for Explosive Atmospheres

WE BUILD IN	WE DON'T USE
EXTREME ACCURACY and DEPENDABILITY maintained during operating life due to direct acting design	**LINKAGES & BEARINGS** which, as they wear, make the setting of the pressure switch drift.
OPERATION IN ANY POSITION which saves the installation costs encountered in mounting a switch that uses liquid switching elements.	**LIQUID SWITCHING ELEMENTS** which make the switch difficult to mount and very critical to vibration.
IMMUNITY TO VIBRATION you can mount the switch directly on your vibrating or moving equipment.	**ACCORDION DIAPHRAGMS** which make the pressure switch sensitive to vibration.

To get complete specifications and operating data ask for bulletins 920-925.

BARKSDALE VALVES

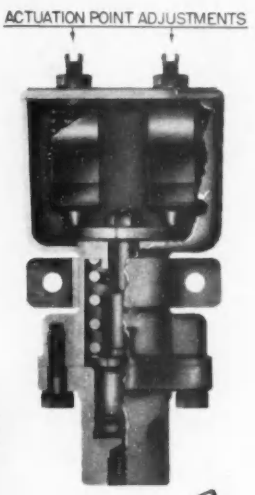
PRESSURE SWITCH DIVISION
5125 Alcoa Avenue, Los Angeles 58, California

NEW PISTON PRESSURE SWITCH

— REALLY TWO FOR THE PRICE OF ONE

Model C9622 is capable of sensing two different pressures in one system and actuating independent electrical circuits at any two desired points, usually a job for two units. Useful where a system pressure must not exceed nor fall below predetermined values.

Simplifies plumbing, cuts installation cost in half, relieves space problems.



*With calibrated dials (both settings can be made visually without gauges)
Without dials $29.50
Both prices subject to the usual quantity and trade discounts.

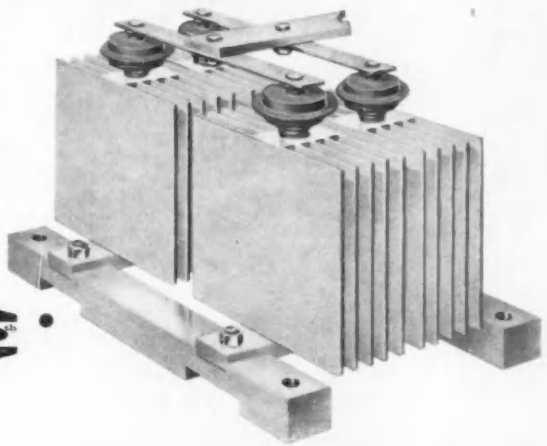
WE BUILD IN	WE DON'T USE
RUGGEDNESS Can take surges— (High proof pressures) Continuous operation— (Millions of cycles) No sticking— (in dirty fluid)	**LINKAGES & BEARINGS** Which wear quickly —(cause settings to drift and switch to fail).
LABOR & MATERIAL SAVINGS No return drain piping— (Sealed piston) Mounts where convenient (Operates in any position, Not sensitive to vibration)	**UNSEALED PISTONS** Which add to your installation cost (return piping). Are critical to dirt— (pistons get stuck).

BARKSDALE VALVES

PRESSURE SWITCH DIVISION
5125 Alcoa Avenue, Los Angeles 58, California
Ask for bulletins 9622 and C9622.

GENERAL ELECTRIC HIGH-CURRENT SILICON RECTIFIERS... NOW IN STACKS

Permits new highs in rectification efficiency with reduced space-weight-cost requirements



These new high-current rectifier stacks supply exceptionally long service without attention or maintenance. There are no moving parts, liquids, vapors, or sensitive electrodes involved. And the fin design provides adequate cooling in many applications without forced air.

The rectifying units proper are the famous 4JA60 Silicon high-current rectifiers produced by the General Electric alloy technique. Hermetically sealed in rugged metal housings, they are protected against damage from moisture, dust, fumes and corrosion.

Silicon high-current stacks are now available, completely assembled to meet your circuit requirements in stacks containing up to twelve rectifying elements. These compact, easily installed stacks may be the answer to your present design problems of big capacity in small space.

TYPICAL APPLICATION...GENERAL ELECTRIC 4JA6011 SILICON HIGH-CURRENT RECTIFIER STACK

CIRCUIT	Three Phase Bridge Rectifier, Resistive Load.
DC OUTPUT	280 volts, 250 amperes, 70 kilowatts.
RECTIFIER LOSSES	Approximately one percent (¾ kw).
COOLING REQUIRED	35°C Free air. Forced air may be used for additional current if desired.
VOLUME	Total volume of assembly—less than ½ cubic foot.

Your General Electric representative will be glad to supply full data. Or, write to *General Electric Company, Semiconductor Products, Section S1657, Electronics Park, Syracuse, New York.*

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NEW PRODUCTS

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Measurement & Data Transmission
Information Display Instruments
Control Devices
Power Supplies
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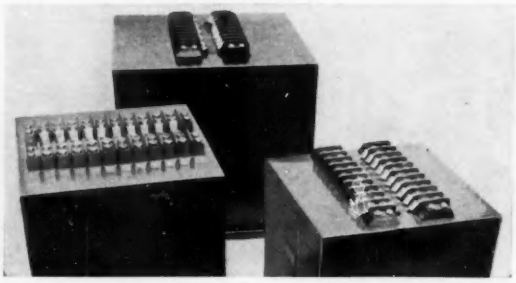
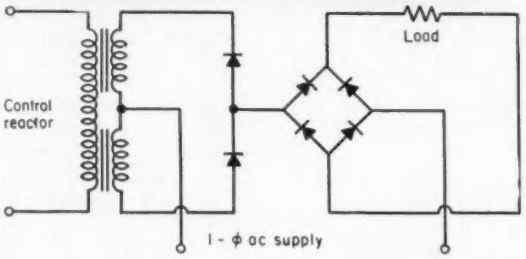
Digital Devices
Component Parts
Accessories & Materials



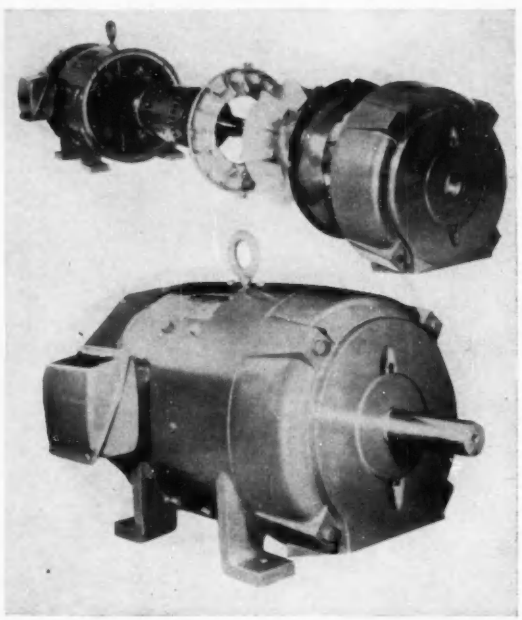


CANNED REACTORS enhance design.

A brand-new line of 22 standard reactor assemblies is now available for a variety of control applications. These include motor-speed control, voltage regulation, arc-welding control, and power amplification of minute outputs from many types of transducers. Except for numbered external terminals, the units are completely encased. Case sizes range from 4 in. sq by 5½ in. long to 9½ in. sq by 9 in. high. Eleven models operate on a 110-volt supply, the others on a 240-volt supply. Average dc voltage-amperes output in both series is from 60 to 1,600. Other characteristics include figures of merit greater than 1,000 and cutoff ratios of 40:1.

As many as eight control windings provide for bias, feedback, mixing, and other control functions. One of the most common high-gain circuits for which these reactors are ideally suited is the single-ended, self-saturating doubler circuit shown at the left. In this particular application, a bridge rectifier is used to provide dc output. Other common dc output circuits include the self-saturating center-tap circuit and the full-wave bridge circuit.—"Control" Div. of Magnetics, Inc., Butler, Pa.

Circle No. 1 on reply card



MOTOR DESIGN cuts inertia 55 percent.

Departing from several traditional design concepts, this new line of dc motors and generators achieves a measure of performance and dependability new to standard dc machines. Among features available for the first time are a high-temperature silicone insulation in machines built and rated to meet low Class B temperature; a controlled ventilation system that improves cooling and cleaning by drawing air from the drive end and expelling it at the commutator end; and a housing design that effectively makes drip-proof machines splash-proof. Longer frames, now standard in the industry, and the new ventilation system combine to reduce the effective armature inertia by as much as 55 percent. This low inertia, plus a 35-percent increase in commutating ability, make the new motors ideal for control applications. The exploded view, left, illustrates the smaller-diameter rotor and the front-end cooling system.

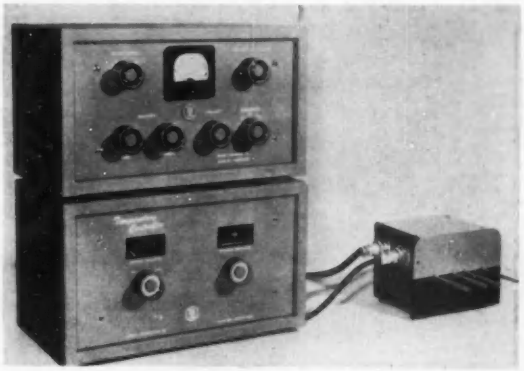
Twenty motor ratings from ½ to 150 hp with base speeds of 300 to 3,500 rpm and 18 generator ratings from ¾ to 100 kw with speeds of 850 to 3,450 rpm permit ample selection. Motors are available with shunt, compound, or series windings. On shunt motors, the large air gaps, oversized field coils, and special pole faces provide near-linear regulation, thereby reducing the control problem in automatic systems.—Westinghouse Electric Corp., Buffalo, N. Y.

Circle No. 2 on reply card

CONDUCTIVITY CELL aids analysis work.

Designated Model 75, this new high-temperature thermal conductivity cell is designed to operate over a range of 30 to 325 deg C, and will handle liquids with boiling points as high as 425 deg C. Its use should appreciably extend the range of chromatographic analyses. Excellent stability and sensitivity at these temperatures is achieved by using flake thermistors as the sensing elements. Each cell consists of a detector enclosed in a specially designed oven, a temperature controller with proportional action, a bridge circuit, and power supply. Manufacturer claims the cell can be incorporated into any existing chromatographic apparatus.—Barnes Engineering Co., Stamford, Conn.

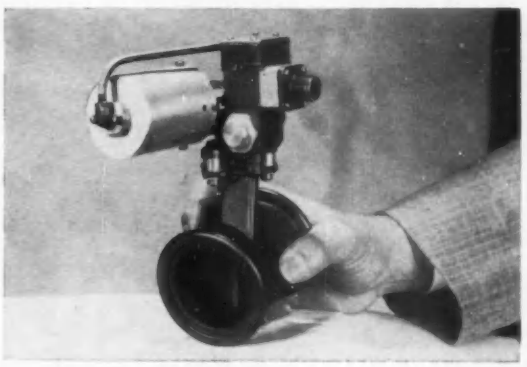
Circle No. 3 on reply card



NEW CONTROL VALVE stands 300 psi.

Photo at right shows a new electropneumatic valve actuator assembly that will operate at up to 300 psi line pressure. Lighter and smaller than electric-motor-driven valves, these units are designed to give maximum leverage at the start of valve opening. In operation, actuating air pressure is drawn off the upstream side of the valve body, passes through an air passage next to the valve stem, and feeds into a pressure regulator that reduces the variable duct pressure to a constant 15 psi for operating the valve. On-off and full modulating types are available, the latter operating in conjunction with a magnetic-amplifier control. Response time is between 1 and 10 sec.—Vapor Heating Corp., Chicago, Ill.

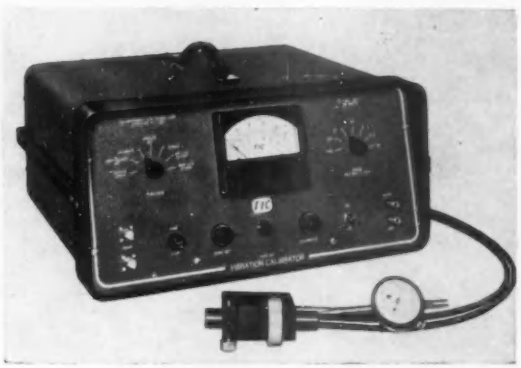
Circle No. 4 on reply card



VIBRATION calibrator spans wide range.

Using a noncontacting probe, the Model 501 Vibration Calibrator will measure vibrations of 10 to 20,000 cps with amplitudes of 20 to 20,000 micro-in. A precision attenuator provides seven amplitude ranges, and accuracy in each is within plus or minus 5 percent. By comparing peak-to-peak displacement of a vibrating surface with a standard displacement, the instrument permits direct reading of output variations. The transducer requires a minimum surface diam of $\frac{7}{8}$ in. Applications involving magnetic and nonmetallic surfaces are accommodated by cementing a piece of copper or aluminum foil, 1 in. in diam, to the surface under the transducer.—Tel-Instrument Electronics Corp., Carlstadt, N. J.

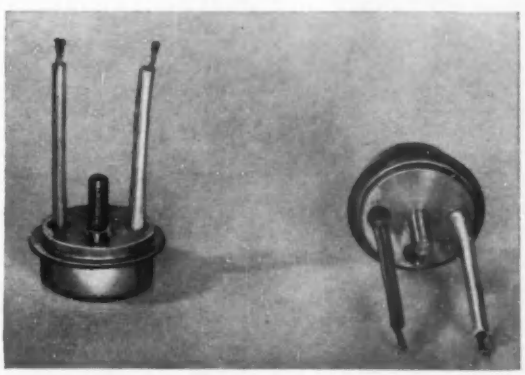
Circle No. 5 on reply card



POWER TRANSISTOR switches 1-kw load.

The Delco 2N174 Power Transistor, now in mass production, is said to be capable of switching a load in excess of one kilowatt. Two advantages of the transistor are: 1) switching an electrical current from a considerable distance using thin wiring, and 2) eliminating arcing at the switch, thus making it safe in explosive atmospheres. This also results in longer switch life and, consequently, higher reliability in industrial control applications. The switching property of the 2N174 can also be used for converting dc to ac with a loss of less than 10 percent of the output power.—Delco Radio Div., General Motors Corp., Kokomo, Ind.

Circle No. 6 on reply card



Rectified **RELAYS** *advance Reliability*

Full wave Rectified, hermetically sealed for 400 cycles.

Improvements, over conventionally operated AC relays, afforded through all frequencies from 25 to 400 cycles by MAGNECRAFT *full-wave rectified* relays, include—

Increased operating sensitivity

Higher contact pressures

Greater resistance to vibration

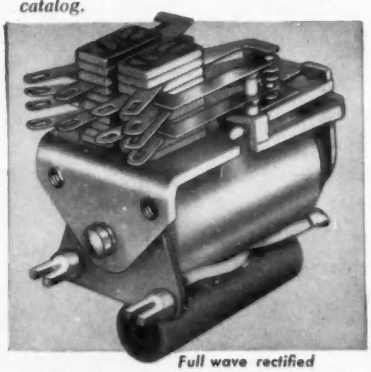
Operation through much wider variation in voltage or current

Quiet operation, free of AC hum

Smaller size

MAGNECRAFT *full-wave rectification* adds nothing to mounting and wiring problems.

Tell us what you need or send for catalog.



Full wave rectified for 60 cycles. Contact combinations to 6PDT

MAGNECRAFT
Electric Company
3354F W. Grand, Chicago 51, Ill.

NEW PRODUCTS

RESEARCH, TEST, & DEVELOPMENT

PRESSURE STANDARD

Operating as an air deadweight tester, this new pressure calibrator has the advantages of a frictionless pressure medium, extreme accuracy even at pressures below 1 psi, and portability regardless of the pressure range. Pressure calibration is achieved by balancing controllable air pressure against the force generated by a weighted piston. When the piston is lifted and suspended by air pressure, a given pressure has been established. This same pressure is fed simultaneously to the device under test. Friction between the piston and cylinder is dispelled by momentarily actuating a motor-clutch assembly, which starts the piston rotating.—Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 7 on reply card

INFRARED SOURCE

A new infrared radiation source, Model CPD-3, is said to provide stable, accurately controlled blackbody infrared radiation over a broad band of temperatures from ambient plus 10 deg C to 500 deg C. Its rugged, compact construction and simple operation suit it for both laboratory and field. The unit may be mounted or unmounted, as a single instrument or in combination with others.—Haller, Raymond & Brown, Inc., State College, Pa.

Circle No. 8 on reply card

TRANSDUCER CALIBRATOR

The Alinco Type C Calibrator, shown above, will calibrate any wire strain transducer. Sensitivity, linearity, hysteresis, and creep can be checked to an accuracy of 0.05 percent. Readout is given directly in percent of full-scale pressure, load, etc.—Allegany Instrument Co., Inc., Cumberland, Md.

Circle No. 9 on reply card

BAR GRAPH SCOPE

A new Navy bar graph oscilloscope, also commercially available, provides simultaneous display of 40 separate signals. It may be used to observe, at a single glance, 40 strain-gage outputs or 40 thermocouple outputs, to monitor multiplexed telemetering channels, and many other applications. A 9-by-12-in. bar graph, on a 17-in. cathode-ray tube, consists of 40 vertical lines. Line height is a linear function of signal amplitude. For increased reading accuracy, each line is terminated with a marking dot at both top and bottom. Drift does not exceed 0.1 percent, and linearity is within 1.0 percent of full scale.—Federal Telephone & Radio Co., Div. of IT&T Corp., Clifton, N. J.

Circle No. 10 on reply card

CURRENT STABILIZER

Model CG-1 Current Governor serves as a two-terminal current stabilizer and programmable electronic load. Current levels at voltages from 0 to plus or minus 3,000 vdc are selected by front-panel controls in 1-ma steps from 1 to 600 ma. Stabilized current

He "quarterbacked" L&N know-how into a finished control system for ETR

This project engineer coordinated the recently completed L&N control system for the 175,000-kw (heat) Engineering Test Reactor (ETR). His function typifies the whole L&N concept of reactor control — standardized components economically "packaged" by men experienced in both steam power and nuclear control.

Applied to the pressurized water-type ETR (built for the A.E.C. by Kaiser Engineers), this L&N control concept resulted in a skillfully integrated system — one that includes all of the reactor's operating and safety channels. A network of Speedomax® monitron recorders was also supplied, to guard constantly against radiation hazards.

In directing work on this system the project engineer drew on a 14-year personal working association with steam power instrumentation. He'd begun building his nuclear background long before his assignment as project engineer for the L&N control systems developed for the Penn State and University of Michigan Reactors.

This project engineer, and others like him, serve as coordinators on every reactor control system produced by L&N. You can direct their experience to your own nuclear control problems merely by contacting us through your L&N office.

Write for our brochure "Control Systems for Nuclear Reactors." Leeds & Northrup Co., 4918 Stenton Ave., Phila. 44, Pa.

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OSCILLATOR CONTROLS

CIRCUIT COMPONENTS FOR ELECTRIC OSCILLATORS

MAINTAIN OSCILLATOR OUTPUT FREQUENCY WITHIN CLOSE LIMITS

ALSO USED AS ELECTRO-MECHANICAL BANDPASS FILTERS

FEATURES

- High accuracy
- Stability of frequency control
- Self starting
- Infinite service life
- Integral, sealed, magnetically shielded
- Standard octal tube pin connectors
- Small, light weight

APPLICATIONS

- Electrical and Acoustical Measurements
- Electrical Communication Systems (Selective Calling)
- Remote Operation and Supervisory Control of Machinery and Apparatus
- Electrical Computers and Telemetering Systems
- Electro-Mechanical Bandpass Filters

Frahm Oscillator Controls, Type ROC, make possible the design and construction of inexpensive, precision tone generators that are small and light weight. These generators will have accurate output frequency and output voltage with very nearly sinusoidal wave shape.

They can be made with any one nominal control frequency between 20 and 1100 cps. They will control the output frequency of circuits, under specified conditions, constant within ±0.15% of the nominal control frequency.

We particularly encourage your inquiries and correspondence on special applications and problems. If you haven't explored these Frahm Oscillator Controls we'll be glad to send you complete specifications, characteristics, etc. Write for Bulletin 34-CE.

B-706

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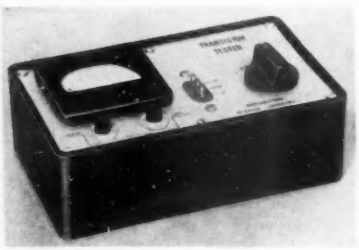
ELECTRICAL TESTING INSTRUMENTS • SPEED MEASURING INSTRUMENTS
LABORATORY & SCIENTIFIC EQUIPMENT
1316 ARCH STREET, PHILADELPHIA 7, PA.

may be modulated up to 100 percent by internal 60-cps sine waves or by external signals including sine waves, complex waveforms, and dc. Applications include transistor and tube testing, magnetic-core investigation, generation of high voltage, long-period sawtooth waveforms, and instrument calibration.—North Hills Electric Co. Inc., Mineola, L. I., N. Y.

Circle No. **11** on reply card

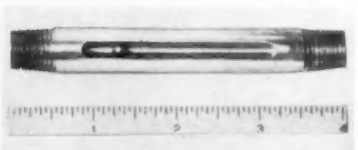


TRANSISTOR TESTER

Built around a high-accuracy D'Arsonval meter movement and long-life constant-voltage mercury batteries, the MH-1 transistor tester, shown above, is an accurate and portable unit, suitable for both field and laboratory use. It tests PNP or NPN transistors for current gain and collector-to-base leakage. Crystal diodes and power rectifiers may also be checked for shorts, opens, or forward-to-reverse current ratio. A useful transistor manual is included with each tester.—Northwestern Research Laboratories, Sacramento, Calif.

Circle No. **12** on reply card

MEASUREMENT & DATA TRANSMISSION



NOVEL ROTAMETER

The tiny rotameter shown above consists of only five parts: a stainless steel or brass pipe nipple with milled

Askania Regulator Company NEWS

Automatic Controls for
PRESSURE, FLOW and COMBUSTION

USEFUL

NEW BULLETIN

Describes
and Illustrates

UNIQUE

Final
Control Element

Here's a well illustrated informative bulletin with ample facts, photos and drawings to show you the advantages of an all electric control system using this unique valve actuator.

Bulletin #38.2 contains the type of information you'll want at your fingertips—such as:

Valve Stem Speed • Valve Stem Thrust • Input Coil Resistance • Power Supply Requirements • Frequency Response • Weight • Oil Capacity

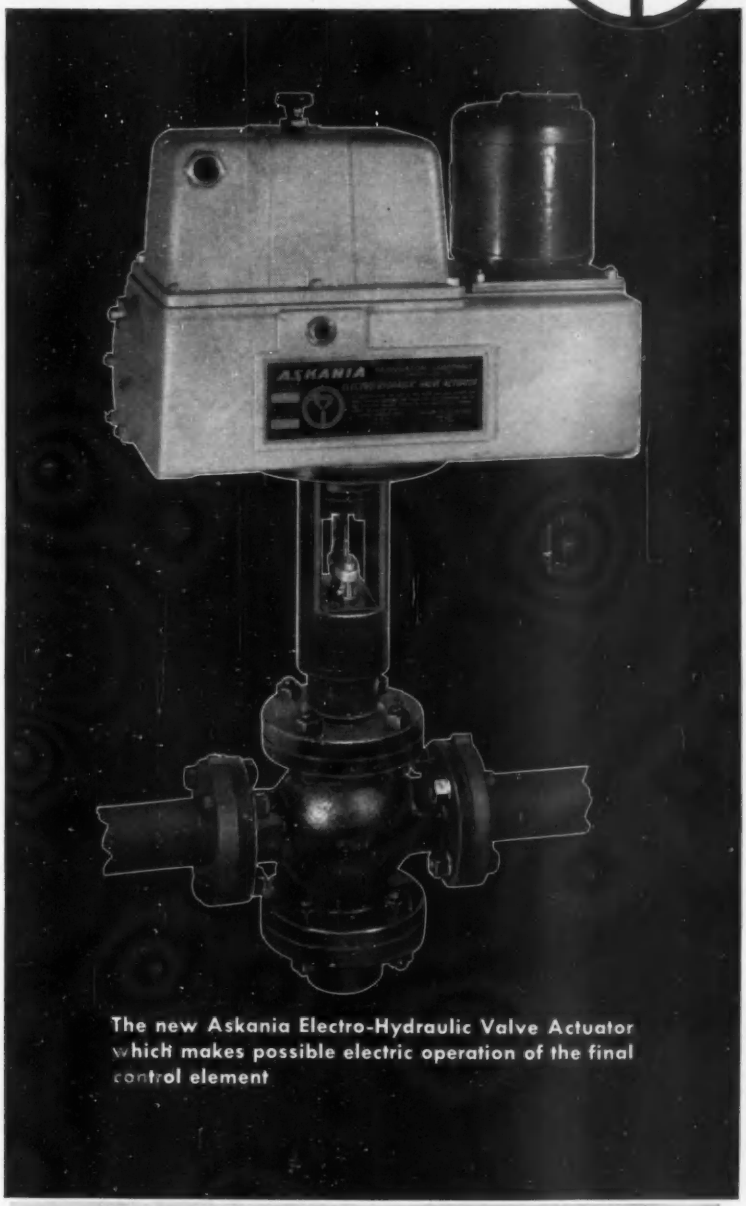
Facts you'll want to know

Bulletin #38.2 explains that the ASKANIA *Electro-Hydraulic Valve Actuator can be:*

1. Adapted to any electronic controller with d-c signal output
2. Applied to any valve up to 8 inches in size and with strokes ranging from ½ inch to 2 inches
3. Adjusted to provide the proper setting for the desired valve stroke
4. Supplied with or without the valve

Be Informed—

Write for your copy of Askania Application Bulletin No. 38.2. Regardless of your present needs, you'll want to know about this novel FINAL CONTROL element. Just write Askania Regulator Co., 266 E. Ontario, Chicago 11, Ill.



The new Askania Electro-Hydraulic Valve Actuator which makes possible electric operation of the final control element

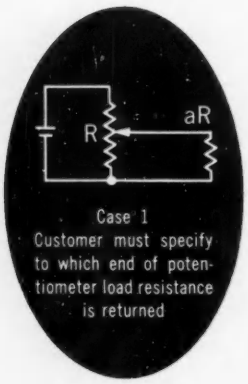
ASKANIA REGULATOR COMPANY
"CONTROLS FOR INDUSTRY"
HYDRAULIC, ELECTRONIC CONTROLS & SERVOS, GENERAL SYSTEMS, ENGINEERING & COMPUTER SERVICE, VALVE ACTUATORS & CYLINDERS

A SUBSIDIARY OF GPE

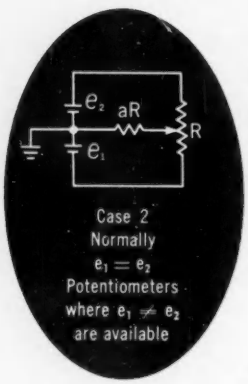
Load-Compensated Potentiometers

for Driving Current-Sensitive Circuits without Isolation or Buffering

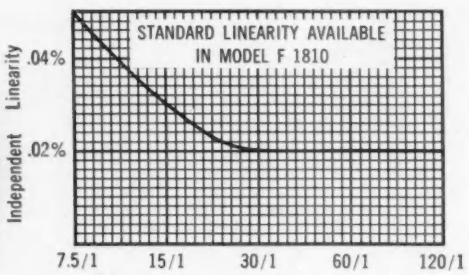
In a load-compensated potentiometer the current into the load is a linear function of shaft rotation. The load-compensated potentiometer is thus a shaft-rotation-to-current transducer, and may be used to drive current-sensitive devices without isolation or buffering. The scale factor of the current-rotation conversion varies directly with applied voltage and inversely with load resistance. The load ratio is permanently specified at the time of manufacture and is "built-in" the potentiometer.

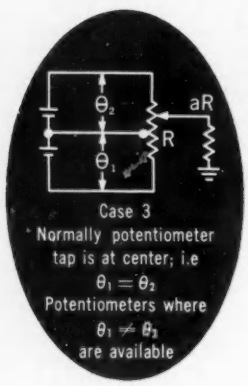


Case 1
Customer must specify to which end of potentiometer load resistance is returned

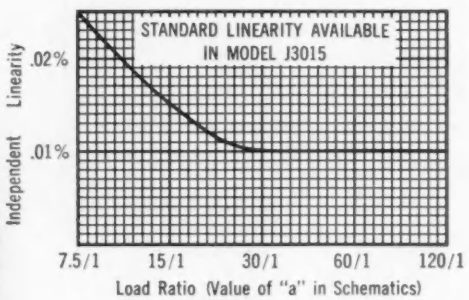


Case 2
Normally $e_1 = e_2$
Potentiometers where $e_1 \neq e_2$ are available





Case 3
Normally potentiometer tap is at center; i.e $\theta_1 = \theta_2$
Potentiometers where $\theta_1 \neq \theta_2$ are available



POTENTIOMETERS MEET NAS-710. Publication P102 describes in detail Analogue Controls Load-Compensated Potentiometers, including complete application information. Write today!

Analogue Controls, Inc.
39 ROSELLE STREET, MINEOLA, N.Y.
PIONEER 2-8901

NEW PRODUCTS

observation slot, a machined lucite meter tube, stainless steel ball, wire stop, and an epoxy resin cement retainer. Maximum static pressure is 1,000 psi, but shock loads to 5,000 psi can be accommodated. Flow rate ranges are 10-100, 20-170, and 100-350 cc per min.—Lester-McKinney, Water Specialists, Inc., Chester, Pa.

Circle No. 13 on reply card

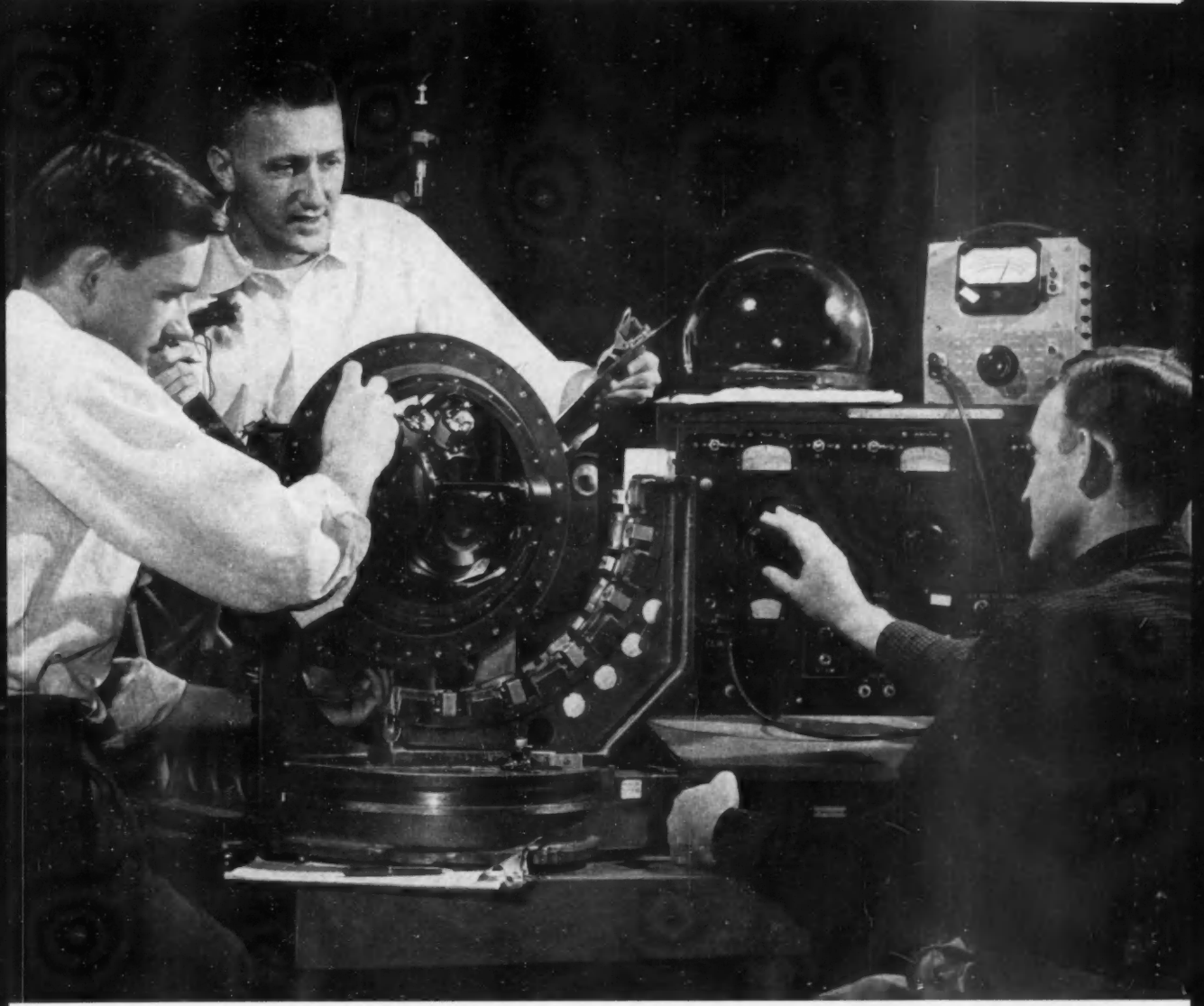
FREE GYRO

This new free gyro, featuring a solenoid-powered caging system, is already in use on new missile systems and other flight-test operations requiring remote caging and uncaging. The caging system has a minimum number of parts and is positive and reliable in operation. Precision potentiometer pickoff can be furnished with taps if desired. The compact unit measures 5½ in. long by 3 in. in diam and weighs about 2½ lb.—Humphrey, Inc., San Diego, Calif.

Circle No. 14 on reply card

PROVIDES 5 MV PER G

The Model 2216 Accelerometer mounts completely within a ⅜-in.



Can you use the talent that built 1,500 Y-4 bombsights on schedule?

These General Mills technicians are representative of the production talent that built more than 1,500 Y-4 bombsights, 1,500 coordinate converters, 1,400 azimuth and sighting angle indicators and 1,400 amplifier and power supply units—and, delivered them to the Air Force *on time*. Here the men inspect a bombsight before it progresses to the next stage of production.

Because we have the highly skilled men—and the men have the specialized tools and machines—we produce precision piece parts or complete, complex assemblies to meet the most exacting requirements.

While building the Y-4 bombsight, we improved original design, exceeded USAF specifications. In addition, our thorough testing facilities assured delivery of only perfect instruments.

Such performance has come to be expected of us and has benefited many other customers. We'd like to help with your production problems too.

Booklet Tells More, explains mechanical and electro-mechanical production facilities. Send to Dept. CE-5, Mechanical Division, General Mills, 1620 Central Ave. N. E., Minneapolis, Minn.

No slow-downs for the B-47—Bombsights ready in advance! During production of the B-47 Stratojet, not a one was kept from the ready-line for lack of a bombsight. The same developmental, engineering and production skills that gave the Air Force on-time delivery are available to speed production of your products.

MECHANICAL DIVISION

CREATIVE RESEARCH AND DEVELOPMENT + PRECISION ENGINEERING AND PRODUCTION

General Mills

NO ONE FILTER MEETS ALL DESIGN NEEDS...

and Only CUNO offers you

5 DISTINCT TYPES OF FILTER MEDIA

♦ EDGE-TYPE ♦ WIRE-WOUND ♦ SCREEN
♦ FIBER CARTRIDGE
♦ POROUS METAL

consider

Super AUTO-KLEAN

where filter design calls for

- ♦ **MICRONIC FILTRATION...** down to 40 microns
- ♦ **POSITIVE, SELF-CLEANING ACTION...** no "down time"
- ♦ **SMALL SIZE plus HIGH FLOW RATES...** 12" unit shown here handles over 50 gpm
- ♦ **LOW PRESSURE DROP...** less than 3 psi

All-metal construction, carbon or stainless steel.
Two-stage filtration. Lowest cost-per-gallon.

COMPLETE DESIGN-ENGINEERING SERVICE

There is a Cuno Field Engineer conveniently located in your area. To help you solve your design problems, this trained specialist offers you *more years of experience* in removing *more sizes of solids* from *more kinds of fluids.*

WRITE FOR DATA

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Send now for your free copy of Cuno Catalog No. SAK-057 containing complete engineering data. See how this high-performance filter can help your designs achieve new efficiency.

CUNO ENGINEERING CORPORATION

2705 SOUTH VINE STREET, MERIDEN, CONN.
Filtration Engineers in Principal Cities

NEW PRODUCTS

hole. Accurate vibration measurements to 10,000 cps can be made by mounting the unit within the device being tested, or mounting it on the surface. Slightly over 5/8 in. high, the new unit provides 5 mv per g sensitivity with a natural frequency of 50,000 cps. Temperature characteristics are flat plus or minus 10 percent from minus 30 to plus 230 deg F. Adapters for surface mounting and a matching $\frac{3}{8}$-in. tap for hole mounting are supplied with the unit.–Endevco Corp., Pasadena, Calif.

Circle No. 15 on reply card

ACCELEROMETERS

Two new series of accurate linear accelerometers are now available. The 1100 Series features a standard voltage output of $2\frac{1}{2}$ or 10 volts with a 26-volt, 400-cycle input. Null voltages are less than 10 mv for the $2\frac{1}{2}$-v output. The 12000 Series has a precision potentiometer output with a resolution of 500. Linearity is better than 0.5 percent and hysteresis less than 0.25 percent. Thresholds lower than 0.001 percent can be achieved.–Technology Instrument Corp., Acton, Mass.

Circle No. 16 on reply card

LOW G METER

Acceleration values down to 0.03 g can be accurately measured with this Model 2218 Accelerometer. A Piezite I ceramic element assures a minimum sensitivity of 40 mv per g. A minimum natural frequency of 20 kc gives a response from 2 cps to over 4,000 cps, with a linearity of plus or minus 5 percent. Response to high-level audio noise fields is virtually eliminated by clamped-crystal design and internal acoustic shielding. Unit weighs only 2 oz.–Endevco Corp., Pasadena, Calif.

Circle No. 17 on reply card

Elongation test of sample heelpiece metal typifies quality control measures that leave nothing to chance at Automatic Electric.

STANDARDS THAT DETERMINE RELAY QUALITY /

a distortion-proof heelpiece

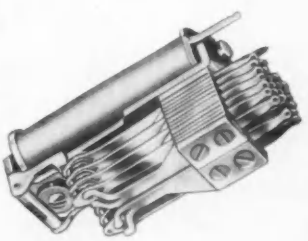
53 dimensional checks assure perfect alignment

The heelpiece of a relay is the platform on which all other parts rest. To maintain accurate contact spacing and pressure, the heelpiece must never shift, never twist, never bend.

We insure flatness and dimensional stability on both Class A and Class B relays, by planishing the heelpiece to relieve strains. In addition, we exercise unusual accuracy in the positioning, drilling and tapping of the holes, in forming the 90° angle bend, and in the contour of the armature end of the heelpiece.

On this single part, fifty-three specified dimensions are maintained and checked—many of which must be accurate to less than 0.002". Rigid tests and inspections safeguard the quality of the raw material itself—a very special sort of magnetic iron.

Care like this in the manufacture of each component makes it clear why Automatic Electric relays are the most reliable that money can buy.



Class "B" Relay, for outstanding endurance and dependability. *Write today for Bulletin 537.* Address: *Automatic Electric Sales Corporation, Chicago 7.* In Canada: *Automatic Electric Sales (Canada) Ltd., Toronto.* Offices in principal cities.

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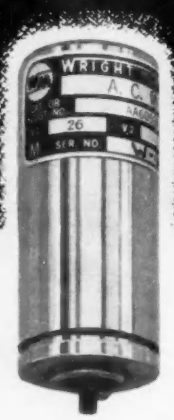
Originators of the dial telephone • Pioneers in automatic control

GENERAL TELEPHONE SYSTEM

MINIATURE CONTROL COMPONENTS

. . a WRIGHT specialty



SIZE 9 SERVO MOTOR TACHOMETER GENERATOR

Diameter: 7/8 inch
Input: 26V-400 cy.
Speed: 9500 RPM
Torque Rating: 0.25 oz.-inch
Generator Output: .33 V/1000 RPM

This two bearing motor-generator set illustrates Wright's exceptional capability for production of special small precision components and assemblies. You are invited to consult us on your next requirements for . . .

A. C. and D. C. Motors · Servo Tach Units
Synchros In All Categories
Gyro Motors · Tachometer Generators
And Related Components and Assemblies

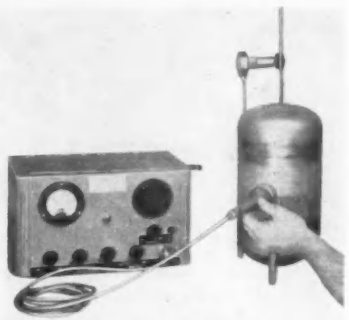
MOTOR DIVISION
WRIGHT MACHINERY COMPANY
ESTABLISHED 1893 · DURHAM, N. C.
DIVISION OF SPERRY RAND CORPORATION

NEW PRODUCTS

FOR WATER PURITY

A new instrument, known as a Salinometer, has been designed for automatically and consistently checking water purity in boilers at set intervals. It will flash a red warning light and sound an alarm if the amount of impurity becomes excessive. The instrument, which operates on the principle that the electrical conductivity of water increases with the amount of salts or impurity present, supplies a low-frequency alternating potential to two "sampling" electrodes immersed in the boiler feed water. A green light indicates the standard of purity is being maintained.—Cossor Instruments, London, England.

Circle No. 18 on reply card



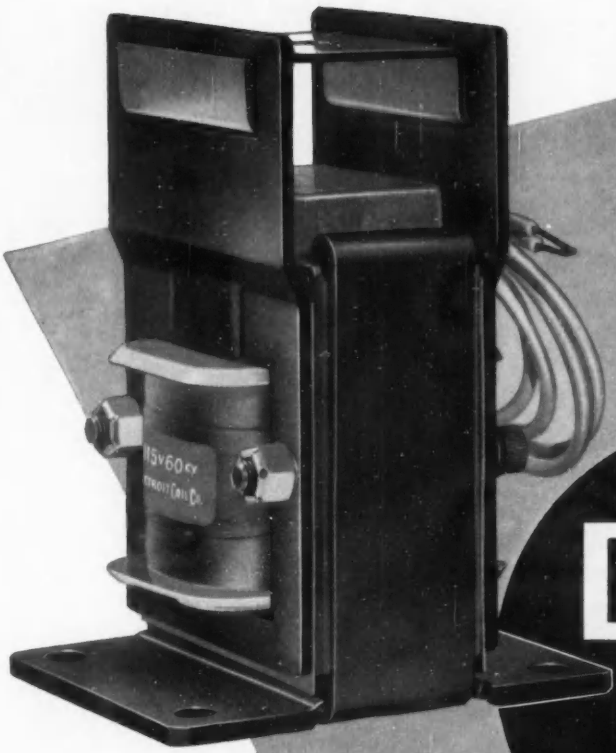
LIQUID-METAL LEVEL

The new liquid-metal level indicator above was developed as part of a liquid metals research program. Sensitive to a 1 mm change in height, the unit employs a balanced inductance bridge circuit, and can be adopted to different container-wall thicknesses by varying the oscillating-signal frequency. Present design limits the container to nonmagnetic wall materials, such as austenitic stainless steel, but future modifications will permit the use of magnetic containers. The probe, made of heat-resistant material, can be shaped as needed.—Nuclear Development Corp. of America, White Plains, N. Y.

Circle No. 19 on reply card

RUGGED MIDGET

Designed to probe pressure changes in formerly inaccessible locations, a new,



- Up to 30 pounds force. Push or pull.
- Full one inch stroke available.
- Decco shock-mounted for long life.
- High efficiency—silicon steel laminations.
- High moisture resistance.
- Shock absorbing bumpers cushion stroke.

Decco SERIES 50

INDUSTRIAL SOLENOIDS

Your choice of mounts

Push or pull types

Direct current solenoids

Decco's Series 50 offers more power—longer stroke with the same dependable quality and performance that has made Decco the top name in industrial solenoids.

There is a Decco solenoid for every requirement. Built to give better service for a longer time. Solenoids engineered and modified to your requirements. Let us discuss your problems.

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Shake well

BEFORE USING!

Vibration . . . with frequencies up to 500 cycles per second and up to 15 G's . . . might prove to be a shattering experience for some servo motors. But *not* for a G-M Servo!

4 GOOD REASONS WHY G-M SERVO MOTORS SERVE YOU BEST!

1. G-M servo motors are available in standard sizes.
2. G-M servo motors can be modified to meet specific circuit requirements.
3. Creative engineering in designing special servo motors with special characteristics.
4. Fast production—better service.

This vibration test at G-M is only one of a series of environmental tests all G-M servo motors must successfully pass—before they can be integrated into your control system.

G-M precision-built servo motors conform to all military environmental specifications when so specified. They are designed to perform under the toughest humidity, salt spray, temperature, altitude and vibration conditions . . . and they come back for more!

Write Now

for information, or send for complete G-M charts and specifications. No obligation, of course.

GM

G-M Servo Motors

manufactured by the Components Division of

G-M LABORATORIES INC.

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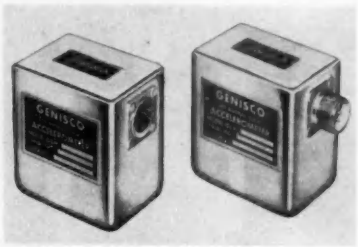
NEW PRODUCTS

variable, resistance-type pressure transducer adds less than 0.004 cu in. to the volume of the system under test. Its simple mounting makes it applicable to many pressure indicating and control problems. It can be used with liquids and gases and has excellent temperature stability from minus 65 to plus 250 deg F. Long exposure to severe pressure transients will not affect its calibration. Full-scale pressure ranges from 1,000 to 5,000 psi are available with full output signals greater than 0.1 volt. Nominal size, exclusive of the 8-32 hydraulic connection, is $\frac{1}{4}$ in. in diam by $\frac{3}{4}$ in. long.—Standard Controls, Inc., Seattle, Wash.

Circle No. 20 on reply card



GOLD-PLATED

Filling the hermetically-sealed cases of these new potentiometer-type accelerometers provides absolute isolation from environmental pressure and humidity changes. The cases are gold-plated to prevent crystalline formations, which have an adverse effect on instrument performance. Balanced range models are available in ranges from plus or minus 1 to 8 g's, or up to plus or minus 30 g's with reduced damping. Unbalanced range instruments and special ultrasensitive accelerometers with ranges as low as 0.1 g can also be supplied.—Genisco Inc., Los Angeles, Calif.

Circle No. 21 on reply card

IDENTIFIES METALS

Based on a design originating in the British Aluminum Co., a tiny, battery-powered electronic instrument identifies nonferrous metals and alloys by measuring electrical resistivity. Specimens can be distinguished provided their specific resistivities are between 1.0 and 28.0 micro-ohms per cc.

DC SOLAVOLT, *shown partly disassembled here, has major components identified. It is designed for relay-rack mounting on a standard, 19" frame or for bench use. Removable handles, for convenience when portability for bench use is desired, are available as accessory equipment.*

Unique combination of components in adjustable "DC Solavolt" regulated power supply reduces conventional size, weight, and cost

Compact size, low weight, high efficiency, and moderate price distinguish the new "DC Solavolt" from conventionally-designed, regulated, adjustable dc power supplies. These outstanding advantages have been secured by using a unique assembly of components (shown above) that occupy only 7" of height and 12¼" of depth on a standard, 19" relay rack frame.

Along with design simplicity, the "DC Solavolt" provides laboratory standards of performance:

OUTPUT VOLTAGE REGULATED WITHIN ±1% at full load with supply voltage variations up to ±15%. (Regulation within ±1.5% at 50% load and lowest voltage setting.)

RIPPLE VOLTAGE HELD WITHIN 0.10% (rms) at full load and nominal input voltage.

An important feature of this adjustable dc power supply is its ability to handle transient or "pulse" loads of up to twice the full load rating of the supply. The "DC Solavolt" has no tubes to replace, requires no "compensating" or "zero" adjustments, and needs no maintenance.

Six stock models provide outputs *adjustable in voltage ranges between 5 and 400 volts and load currents up to 7 amperes.* Your local electronic distributor now has the "DC Solavolt" in stock. He will be happy to give you further, technical information.

SOLA *Constant Voltage* **DC POWER SUPPLIES**

Write for Bulletin 26E-DC-245
SOLA ELECTRIC CO.
4633 W. 16th Street
Chicago 50, Illinois

CONSTANT VOLTAGE TRANSFORMERS • FLUORESCENT LIGHTING BALLASTS • MERCURY VAPOR LIGHTING TRANSFORMERS
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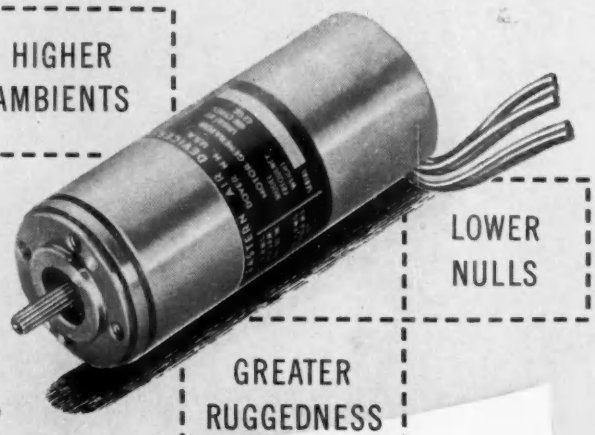
EAD announces an unusually precise

SERVOMOTOR-TACHOMETER GENERATOR

HIGHER AMBIENTS

LOWER NULLS

GREATER RUGGEDNESS



SIZE 11
SJ1HLX7
(Actual size)

for
INSTRUMENTATION
FIRE CONTROL
AUTOPILOTS
MISSILES
COMPUTERS

FEATURES:

Zero Speed Voltage (RMS)	8.0 mv in phase 15.0 mv quadrature 19.0 mv total
Max Ambient Temp.	150°C
Linearity	0.5% to 3600 rpm
Output Gradient Phase Shift	0.5V/1000 rpm (min.) ±10%

Servo motor meets Bu. Ord. MK-14 specifications.
Equipped with precision gearhead for lower backlash.
Rugged, one-piece assembly.

WRITE for complete detailed information

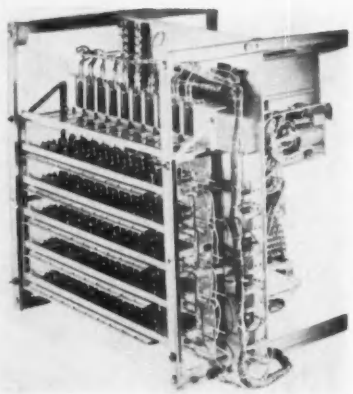
EASTERN AIR DEVICES, INC.
SOLVING SPECIAL PROBLEMS IS ROUTINE AT EAD
375 CENTRAL AVENUE • DOVER, NEW HAMPSHIRE

NEW PRODUCTS

Minimum requirements are that the surface of the metal must be fairly smooth, and that the portion to which the probe is applied must have a minimum thickness of about 0.02 in. and a minimum width of 0.75 in. —The Solatron Electronic Group, Surrey, England.

Circle No. 22 on reply card

INFORMATION DISPLAY INSTRUMENTS



CROSSBAR SCANNER

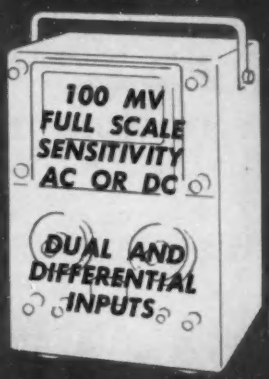
This versatile, low-cost, self-contained crossbar scanner is capable of scanning 200 points sequentially in response to a contact closure. Provisions are made for start and stop scanning at predetermined points, for skipping groups of points, and for controlling external devices at each point (by contacts). Other features include low-contact resistance, low thermoelectric potentials, high leakage resistance, and very good high-frequency performance.—James Cunningham, Son & Co., Inc., Rochester, N. Y.

Circle No. 23 on reply card

TOTALIZING COUNTER

A new dependable, direct-reading, high-speed electronic counter, designed for industrial and special-purpose counting, will totalize any electrical, mechanical, or optical event that can be converted to an electrical impulse. Specs include: models with

New Du MONT TYPE 405 VTVM



Now there's no need to weigh feature against feature when it comes to vacuum tube voltmeters — the new Du Mont 405 has everything!

The 405 is the first VTVM to combine **100 millivolt** full scale sensitivity, either **AC or DC,** with **dual and differential inputs.** Besides, it features DC performance from **2 millivolts to 1000 volts** with **120 megohm input.** It doesn't stop there, for it also offers highly accurate AC performance from **below 50 cps** up into the **UHF range.** As an **ohmmeter,** the Type 405 is calibrated from **0 to 500 megohms,** in eight ranges.

Another in the outstanding Du Mont 400 Series, the 405 is "human engineered" for ease and convenience of operation, reliability, and precision. Its rugged construction is backed by the exclusive Du Mont 5-year guarantee offered with all instruments of the 400 Series.

Price **$265.00**

Slightly higher in 50-cycle areas.

Write for complete details

FEATURING

- **ACCURACY:** 2%.
- **SCALE:** Illuminated 4" mirror-backed scale for accurate readings.
- **STABILITY:** Very low drift. Less than ± 3 millivolts on any range.
- **VERSATILITY:** Designed for safe off-ground operation up to 1000 volts DC.
- **REGULATED:** Regulated DC and filament supply.
- **AMPLIFIER OUTPUT:** Amplifier output available with power gain over 60 db.
- **SIZE:** Compact, weighs only 12 pounds.
- **PROBE STORAGE:** Built-in probe storage compartment.

DU MONT®

One of the 400 Series

Technical Sales Department, ALLEN B. DU MONT LABORATORIES, INC., Clifton, N. J.

PROBLEM #1

Design a charging reactor with an inductance of 4.85 henrys (±7%) at 150 ma, DC, and an inductance linearity of 20%. It should operate at 8000 volts DC, be tested at 14,000 RMS volts, and continuously useable in the frequency range up to 2000 cps. It should have a maximum temperature rise of 125° C in a standard ambient, also a maximum effective capacitance of only 60 micromicrofarads when measured in the frequency range between 20 and 25 megacycles. Other prime factors are minimum weight and dimension. Construction to be in strict accordance with the applicable requirements of MIL-T-27.

SOLUTION BY PEERLESS

Inductance	4.85 henrys ± 5% @ 150 ma, DC
Linearity	10%
Operating Voltage	DC = 8000
Test Voltage RMS	16,000
Useable at F up to	2000 cps
Maximum Temp. Rise	100° C
Ambient Temperature	25° C
Max. Effective Cap.	51 micromicrofarads (measured at 20-25 megacycles)
Weight	2-3/4 lbs.
Dimensions, nominal	H—3-1/2" ± 3/8" terminal W—2-7/8" L—3-13/16"

The outstanding success of the Peerless engineering staff in the development of transformers to meet unique and difficult specifications has made Peerless transformers the first choice of engineers throughout the country. Custom production techniques and stringent quality control assure a dependable product.

Consult Peerless for the best solution to your quality transformer requirements.

PEERLESS Electrical Products A DIVISION OF ALTEC LANSING CORPORATION

1515 S. Manchester Ave., Anaheim, Calif. • 161 Sixth Avenue, New York 13, N.Y.

NEW PRODUCTS

from 1 to 4 decades; count capacities from 999,999 to 999,999,999; counts per sec ranging from 0-150 to 0-100,000; and input requirements of 0.05 volt rms.—Computer-Measurements Corp., North Hollywood, Calif.

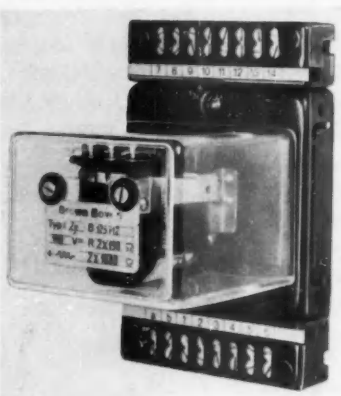
Circle No. 24 on reply card

FIBER-GLASS CASES

Plastic-impregnated fiber-glass cases are being used to house a new line of low-cost instruments for indicating, transmitting, and controlling pressure and temperature. The fibre-glass case makes this line particularly suitable for use outdoors or in corrosive atmospheres. Color of the case is not just a surface finish, but extends throughout the material. Temperature range of the new series is from minus 400 to plus 1,000 deg F. Pressure range is from 30 in. Hg vacuum to 5,000 psi. As pneumatic receivers, the instruments can accommodate 3 to 15, 3 to 18, or 3 to 27 psi signals.—Fischer & Porter Co., Hatboro, Pa.

Circle No. 25 on reply card

CONTROL DEVICES



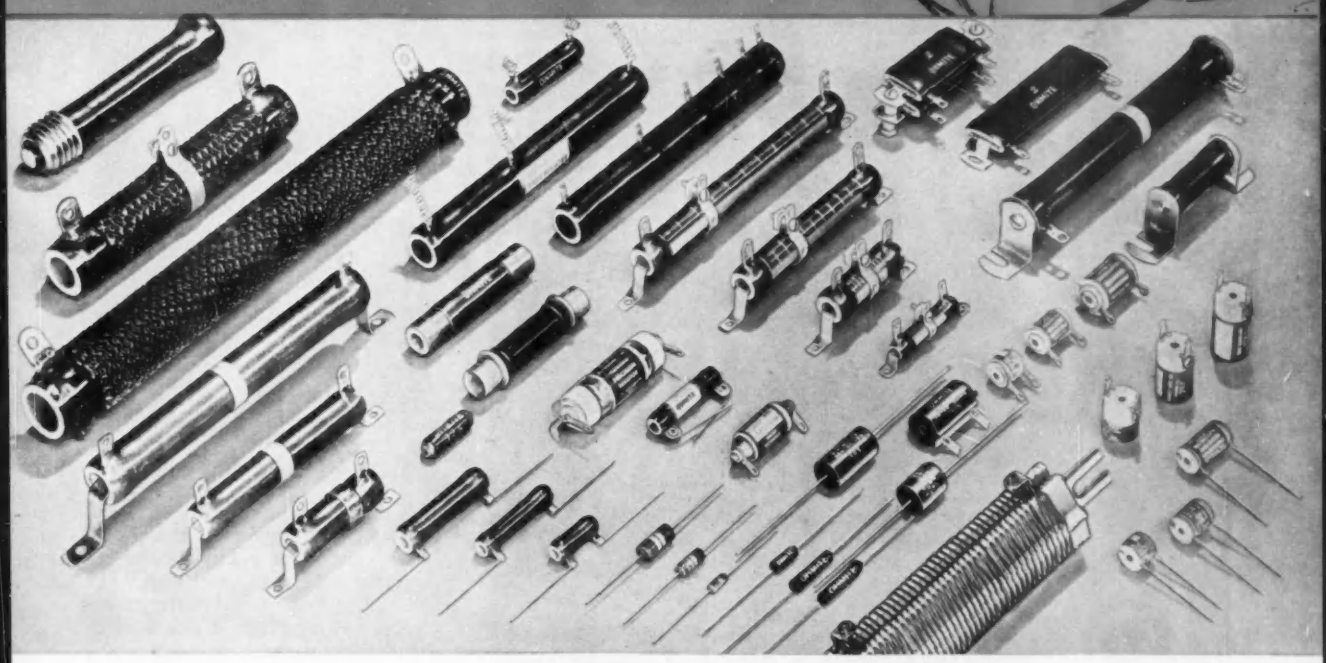
DC CONTACTOR

Designed for continuous duty, this high-speed dc contactor has a pickup time of approximately 1/10 cycle. It is said to be well-suited for applications where speed, reliability, and long operating life are important. Units are available with either four normally

OHMITE®

has exactly the resistor you need

Ohmite offers the most complete line of wire-wound resistors on the market . . . fixed, adjustable, tapped, non-inductive, and precision resistors in many sizes, types of terminals . . . in a wide range of wattages and resistances.



Industry's most complete line of wire-wound resistors!

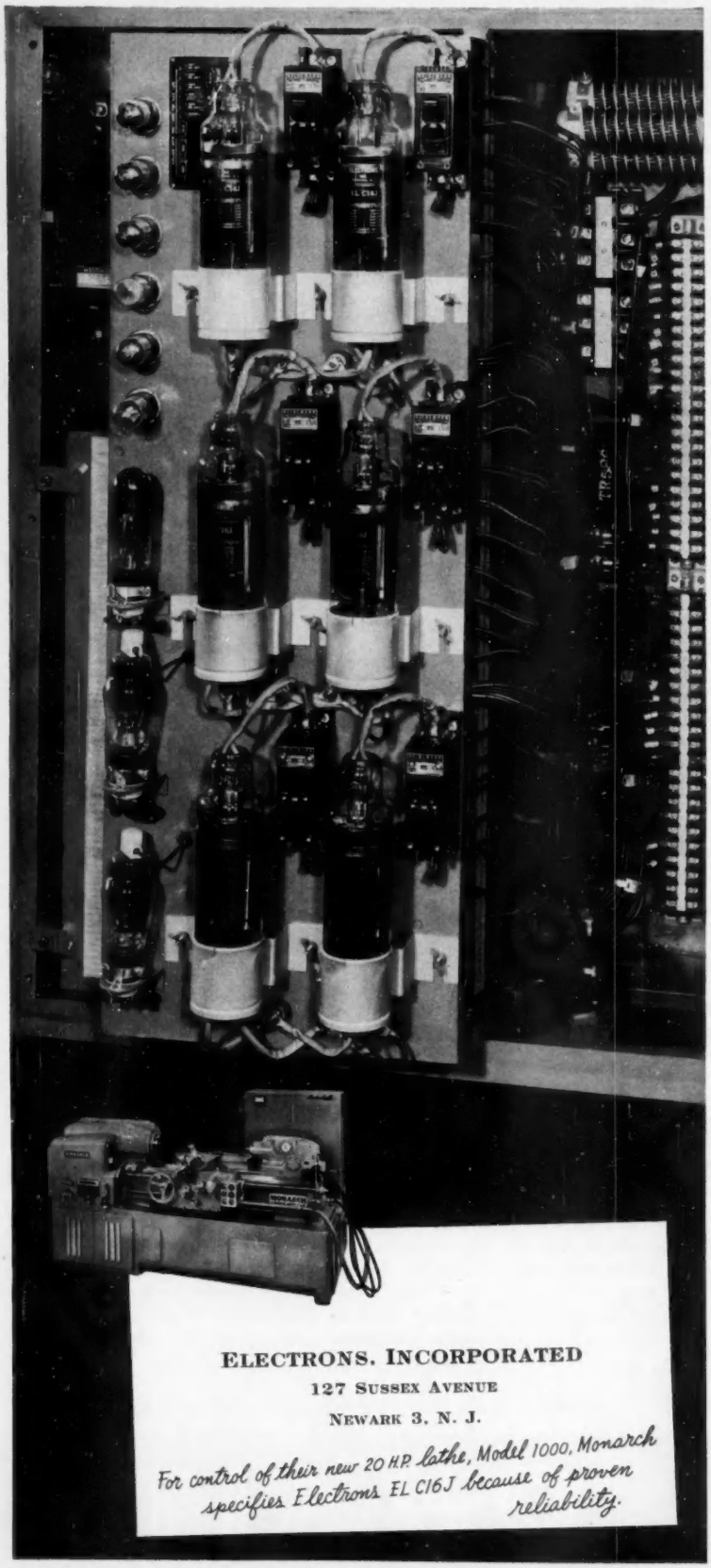
The extensive range of Ohmite types and sizes makes possible an almost endless variety of Ohmite resistors to meet each individual need. Ohmite offers resistors in more than 60 sizes—ranging from 2½" diameter by 20" long to ¼" diameter by $\frac{9}{16}$" long—to meet your exact requirements. MANY SIZES ARE CARRIED IN STOCK. These rugged resistors have proved their quality under the toughest operating conditions. Ohmite application engineers will be pleased to help you in selecting the right resistors for your job.

Write on company letterhead for
Catalog and Engineering Manual No. 40.

OHMITE MANUFACTURING COMPANY, 3674 Howard Street, Skokie, Illinois (Suburb of Chicago)

Be Right with **OHMITE®**

RHEOSTATS • RESISTORS • RELAYS • TAP SWITCHES


ELECTRONS, INCORPORATED
127 SUSSEX AVENUE
NEWARK 3, N. J.
For control of their new 20 H.P. lathe, Model 1000, Monarch specifies Electrons EL C16J because of proven reliability.

NEW PRODUCTS

open contacts, four normally closed contacts, or two normally open and two normally closed contacts. Contacts have a sustained current rating of 5 amps; their making current is given as 20 amps. There was no noticeable wear after a test of more than 2 million operations. Mounted as shown above, the unit measures 5¼ by 3½ by 4¼ in., including the transparent plastic cover.—Brown Boveri Corp., New York, N. Y.

Circle No. 26 on reply card

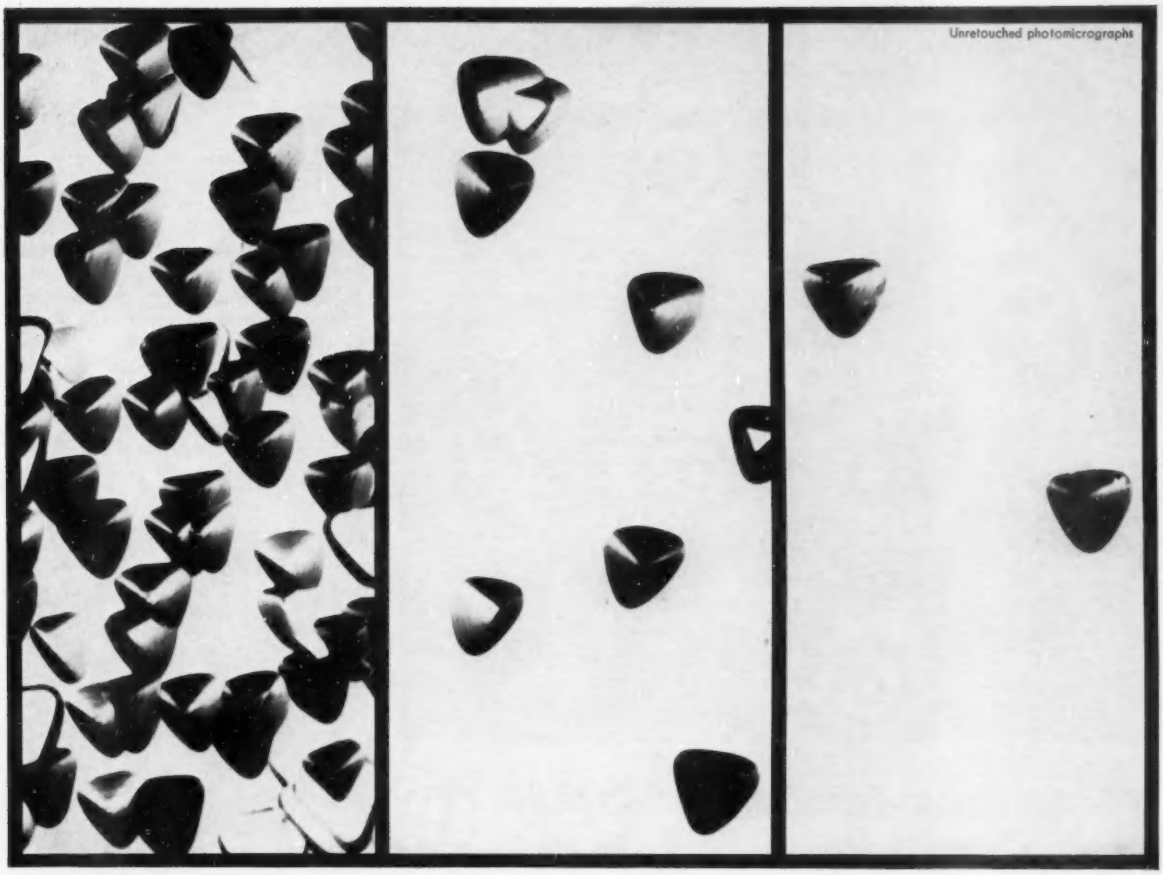
MOTOR CONTROLLER

This new electronic controller is said to provide accurate acceleration and speed control of shunt wound dc motors from 1/50th to ¼th hp. The acceleration control starts the motor at any speed from 1 to 2,200 rpm, either immediately or gradually over a 30-sec interval. The fine-speed adjustment works in conjunction with the coarse speed control. Motor speed may be accurately and steplessly varied by as little as 220 rpm with 270 deg of speed pot turning. A C3J thyratron automatically increases voltage to compensate for additional loading of the motor armature—Gerald K. Heller Co., Las Vegas, Nev.

Circle No. 27 on reply card

DRAFT CONTROLS

A new line of automatic draft controls is now on the market. A Draft Program Control, in conjunction with a

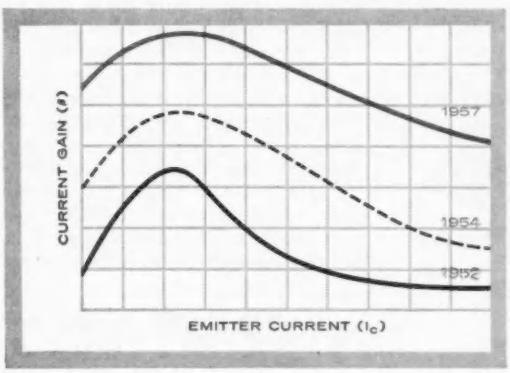


1952 Germanium crystals average many of these triangular "dislocations" or imperfections, here magnified 200 diameters.

1954 Processing improvements are bringing dislocations under better control, but density can be further reduced.

1957 Mechanized growing of CBS single crystals has uniformly minimized dislocations. Density is that of purest diamonds.

How more-perfect crystals improve transistor performance



BETA Note the higher Beta or current gain (other factors being equal) derived from today's perfected CBS germanium crystals. Beta is used as just one concrete example of many important performance factors improved by CBS-Hytron's better crystal processing methods.

How does CBS grow uniformly dislocation-free crystals with uniform resistivity? By precise checking of the "seed" for orientation and dislocation density. By growing the single crystal in smoothly operating, shock-proof mechanized furnaces. By automatic temperature control and a uniform temperature gradient throughout the growing period. Research and development advances like these are constantly at work to make CBS transistors better.

And you can *see* the difference in quality that is built not tested into CBS transistors: In crystal photomicrographs. In Beta and other figures of merit. And in actual performance. Try CBS transistors and see for yourself.

CBS semiconductors

Reliable products through Advanced-Engineering

CBS-HYTRON
Semiconductor Operations, Lowell, Mass.
A Division of Columbia Broadcasting System, Inc.

These BS&B Rupture Discs Can Give Your Pressured System...
Standard Rupture Discs, prebulged... available in a broad range of sizes, pressures and metals.
Vacuum Supports . . . installed under prebulged rupture discs to prevent their collapse under vacuum; fit exact disc contours.
Plastic Linings . . . and coatings for protection of prebulged discs under any specific corrosive condition.
Model D & DV Rupture Discs . . . for high temperature, pulsating pressure and corrosive services. Model DV includes vacuum support.
Model 1A & 1B Rupture Discs . . . for lower rupture pressures than prebulged discs; excellent for corrosive services. Model 1B includes flat vacuum support.

Positive Pressure Protection From 3 To 50,000 PSI

Installing a BS&B Rupture Disc on a pressured system provides protective insurance against a major disaster. Thousands of BS&B Safety Heads, each containing a BS&B Rupture Disc custom made to meet the individual requirements of the system it protects, are now guarding pressured systems in all types of industries.

Fully accepted by most local and national codes for use as either primary or secondary pressure relieving devices, BS&B Rupture Discs can be *your* positive and final measure of protection for the unexpected emergency.

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THE "CIRCUIT BREAKER" of Pressured Systems

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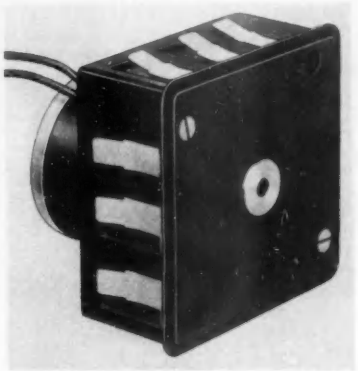
Safety Head Division, Dept. 2-E55.
7500 East 12th Street
Kansas City 26, Missouri

NEW PRODUCTS

Modulating Damper Actuator, maintains a correct draft for all firing conditions, and assures safe starting by opening the uptake damper prior to burner ignition. Companion instruments include a flue-gas-temperature indicator, a draft gage, and a steam-pressure controller/indicator. The latter will control fuel rate to the burner in response to steam pressure charges. Units feature cast-aluminum cases for either flush or surface mounting.—General Controls Co., Glendale, Calif.

Circle No. 28 on reply card



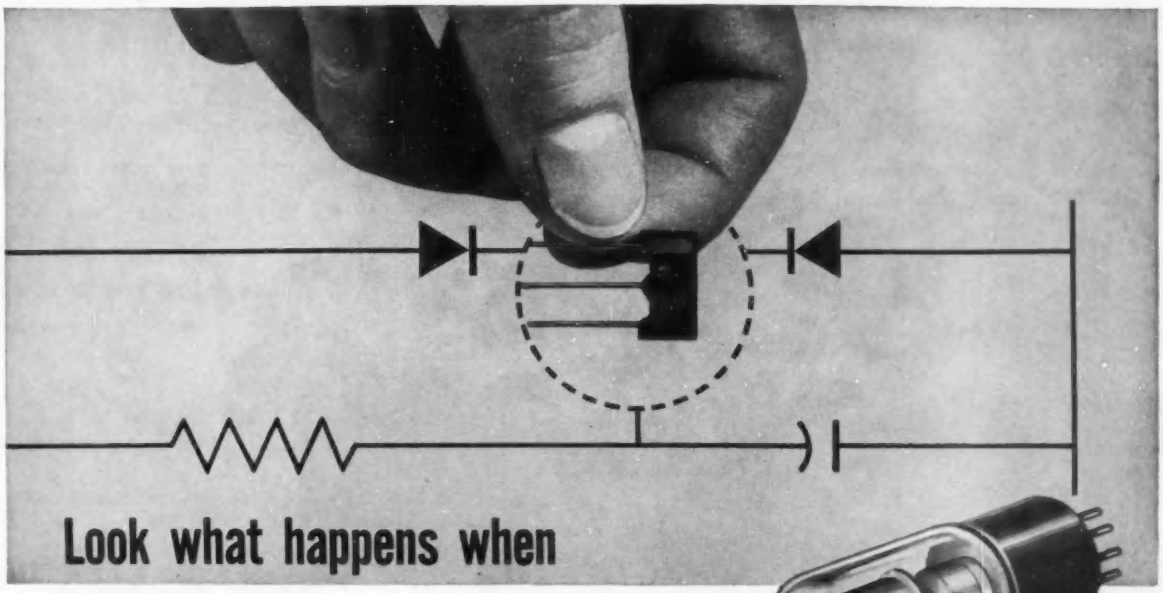
CYCLING TIMER

This new timer, Type 571, is a cycling device that operates continuously as long as power is supplied to its high-torque motor. Contacts are rated for 30 amp resistive loads at 115 vac, and speeds of 1 rpm to 1 revolution in eight days are available. Time program is cut into factory-set cams, which are securely positioned on a square shaft. Overall dimensions are approximately 2¾ in. sq by 2¾ in. deep, including motor. Switches are open blade, either SPST or SPDT.—Cramer Controls Corp., Centerbrook, Conn.

Circle No. 29 on reply card

INTERVAL TIMER

Another timer by Cramer Controls has a molded bakelite case that houses one or two SPDT or SPST open-blade switches rated at 30 amps, 115 vac resistive and 1/3 hp at 115 vac. Its permanent magnet synchronous motor drives precision-cut cams which actu-



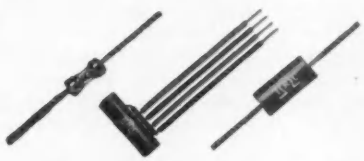
Look what happens when

MICROSTAK diodes replace tubes

By replacing dual diode vacuum tubes with MICROSTAK Selenium Dual Diodes, you can now save space and money in many low current applications calling for high back resistance and low forward resistance. These IRC components not only eliminate all the added bulk, sockets, and assembly connected with tubes, but are also economical to buy and use.

MICROSTAK Selenium Dual Diodes cover a microampere to milliampere current range at voltages as high as several thousand volts. Furthermore, they are available in molded plastic, hermetically sealed glass, and other enclosures. As a result, MICROSTAK Selenium Diodes deliver the performance you want in power supplies, voltage regulators, balanced modulators, arc suppression, meter overload protection, logarithmic converters, magnetic amplifiers, and many other applications.

FEATURES OF MICROSTAK DIODES



- Expertly designed to individual customer requirements
- Available in single or multiple cell types
- Supplied to much closer limits than ordinary diodes
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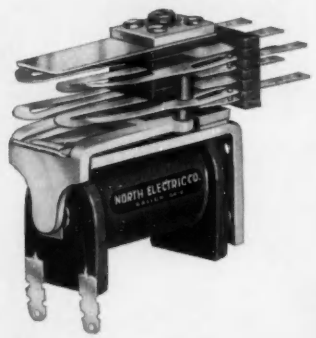
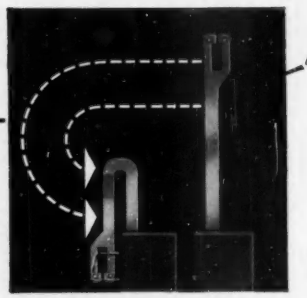
IRC

telephone | *quality in a miniature relay?*



yes!

IN NORTH "M" TYPE RELAY!



Note the "U" shape of the lever springs. From the pile-up, the lever spring extends the full length of the coil, then doubles back an equal distance to the fixed contact points.

Stability of operating characteristics, with which relay dependability is achieved, can be maximized by a configuration which puts the fixed contact springs as close as possible to the clamping axis of the pile-up and yet escapes the penalty of the greatly foreshortened lever spring common in miniaturized relays.

In the North "M" Relay, both requirements have been met.

The fixed contact springs are lateral extensions from the anchoring pile-up, minimizing any possibility of post-adjustment variation.

The unique "U" design of the lever springs in North's "M" Relay enables it to meet critical space requirements while retaining lever spring length to achieve telephone dependability.

The armature in North's "M" type relay operates on a knife hinge—never needs lubrication, and the small amount of armature travel provides fast operation.

Lightweight operating parts keep contact bounce at an absolute minimum.

North's "M" type relay can be furnished with 6, 12, 24, 48, or 100 Volt coils; 1, 2, or 4 DPDT standard spring arrangements; with double gold or single silver contacts; with dust cover and octal mounting plug.

North's "M" type relay is available from stock.

Length 1-13/16", Height 1-1/4", Width 25/32", Weight 1.8 oz.

INDUSTRIAL DIVISION

NORTH ELECTRIC COMPANY

745 SOUTH MARKET STREET • GALION, OHIO

Available in Canada through Ericsson Telephone Sales of Canada, Ltd., Montreal 8, P. Q.

NEW PRODUCTS

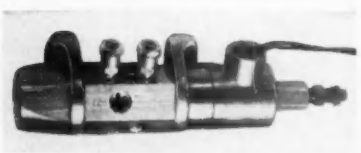
ate the switches at full-scale intervals lasting from 45 sec to 6 days. Ranges shorter than 45 sec are available with lower contact ratings.—Cramer Controls Corp., Centerbrook, Conn.

Circle No. 30 on reply card

VERSATILE LIMIT SWITCHES

This new precision limit switch features rugged construction and versatility. Its versatility comes from interchangeable components. Three actuators and three housings permit the switch to be arranged in 16 different ways. Actuators include a plunger, roller arm, and roller plunger types. Die-cast aluminum housings provide a strong enclosure, adequate wiring space, and an internal tap conduit hub.—Licon Div., Illinois Tool Works, Chicago, Ill.

Circle No. 31 on reply card



0-TO-30-SEC TIME DELAY

Now in production, a new solenoid-operated time-delay air valve provides a time delay between the release of the electrical impulse on the solenoid and the return of the cylinder to its original position. Delay time is adjustable between 0 and 30 sec, with a repetition accuracy of plus or minus 10 per cent. No special switching is needed. Port sizes range from ¼ to 1 in.—Beckett-Harcum Co., Wilmington, O.

Circle No. 32 on reply card

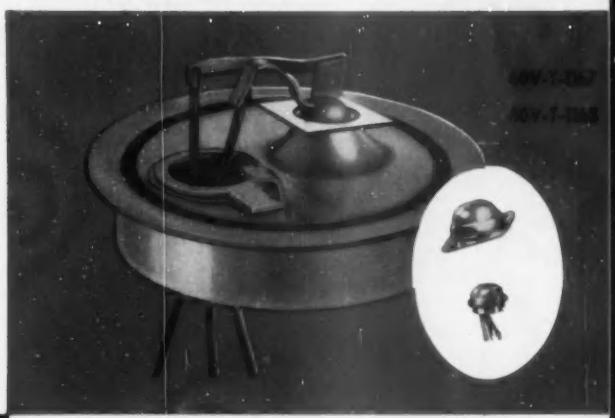
PNEUTRONIC *Level Control Provides*

New!.... FROM TRANSISTOR CENTER U.S.A.

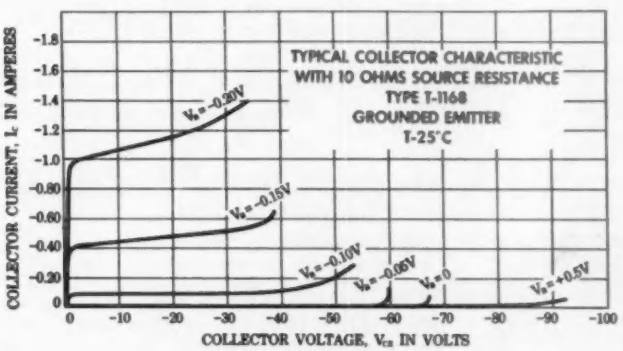
PHILCO 60V and 80V Power Transistors

Designed for servo, control, power converter and power supply applications.

Here are extremely reliable, moderately priced, high voltage power transistors—immediately available in production quantities. These transistors perform with a typical thermal drop of only 1½°C per watt . . . with storage temperature of 100°C. They have high beta at high currents . . . improved alpha cut-off . . . low surface leakage currents . . . low saturation resistance . . . low distortion. Both transistors operate at power load of 12.5 watts. The unique *knee-action* between the aluminum mounting clamp and the copper mount assures maximum dissipator contact at all times.



Philco cold-welding process permits hermetic sealing in controlled atmosphere . . . assuring exceptional transistor life and performance!



Philco transistors, after vacuum baking, emerge into a controlled atmosphere . . . where they are welded to insure perfect sealing for life. This process eliminates contamination of the transistor elements by moisture or atmosphere. Uniformity and quality control are strictly maintained throughout.

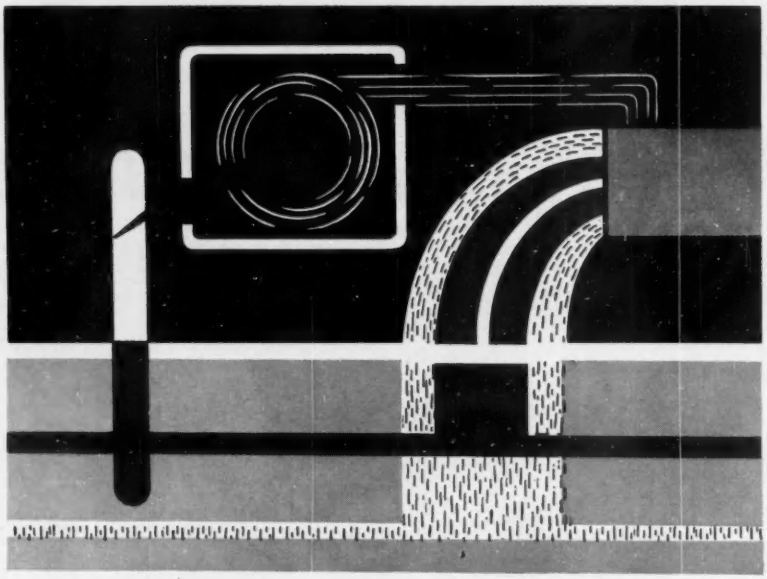
Write for complete data and prices. *Make Philco your prime source of information for power transistor applications!*

PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

PNEUTRONIC *Level Control Provides Proportioning Action at Low Cost*



The new Fielden Pneutronic Level Control proportions flow and maintains level simply by combining an electronic "dip stick" with a proportioning pneutronic control. This dip stick has no moving parts, yet actually "senses" change in level and integrates the electronic and pneutronic units into a simple, dependable null-balance system.

Electronically, the PNEUTRONIC Level Control features the versatile electrical capacitance method of measurement. As a result, it can detect minute changes in the level of any liquid, powder, or granular solid—conducting or non-conducting. The resulting change in capacitance changes output air pressure *directly*, and this output air then feeds back to balance the electronic circuit *directly*.

FEATURES

- Null-Balance System
- Only one vacuum tube
- Control pressure 3 to 15 psi
- No moving parts in vessel
- Controls water level up to 1½" span, hydrocarbons up to 8"

SIMPLIFY RECORDING AND CONTROL WITH *Fielden*

Through interchangeable input conversion units and re-balance elements, the same basic Fielden Null-Balance Recorder can record temperature or any other process variable. Other assemblies can be added for recording up to 96 points on one circular chart, for electric control, or pneumatic proportional control. Fielden also supplies other recorders, blind on-off controllers, manual monitors, automatic scanners, and a full line of sensing elements, supplies and accessories.

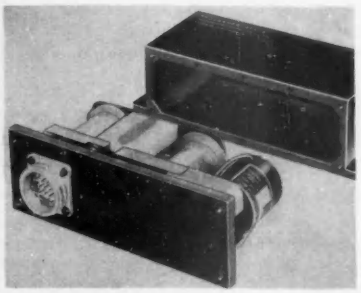
Send for Literature

Mr. Controls®

Robertshaw-Fulton CONTROLS COMPANY

FIELDEN INSTRUMENT DIVISION
Dept. S, 2920 N. 4th St., Philadelphia 33, Pa.

NEW PRODUCTS

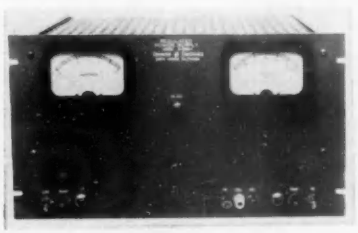


PROGRAMMER

Though small in size and light in weight, this new programmer provides up to 13 channels for any type of electrical programming, either of a repeat cycling or of a random nature. Designed for missile and aircraft applications, the device has an accuracy in the order of one part in 50,000. Close manufacturing tolerances and a high-strength magnesium casting assure resistance to shock and vibrations without imposing a high weight penalty. In operation, an insulating tape similar to 35-mm photographic film advances at a precise speed between 13 contactors. The tape is marked lengthwise in time and divided into 13 channels. By punching holes or slots in the control tape, allowing the contactors to close for different periods of time, up to 13 control signals can be generated.—Photographic Products Inc., Anaheim, Calif.

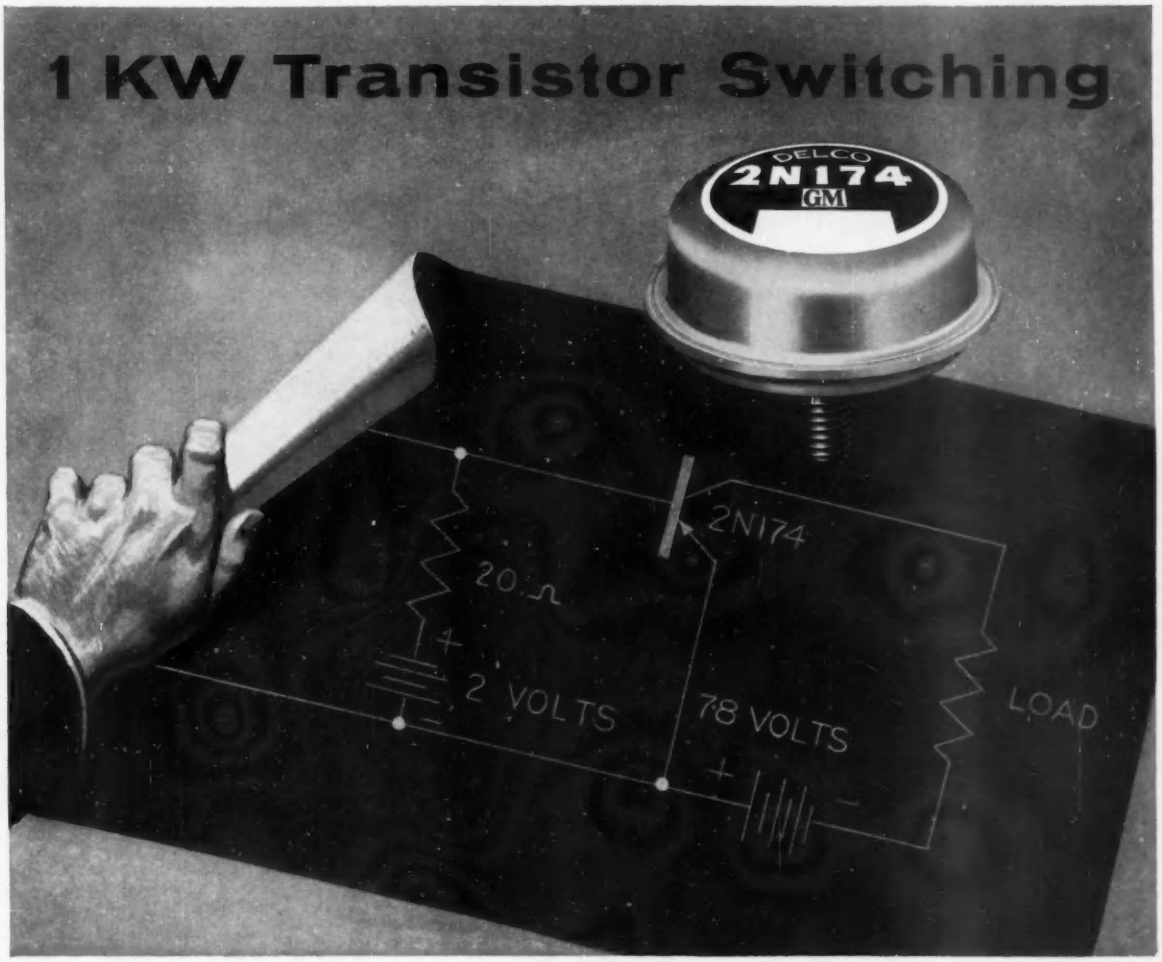
Circle No. 33 on reply card

POWER SUPPLIES



REGULATED POWER

A new series of heavy-duty, high-current, regulated-dc power supplies contains 84 models in 1-, 2-, and 3-amp current ranges. The 2- and 3-amp models feature forced air cooling to



Industry's Highest Power Transistor

Eliminate arcing at switch points. Stop switch deterioration while increasing the efficiency and reliability of all electronic control equipment!

A single Delco 2N174 transistor can switch 1 kw with one watt of control power.

Because transistor switching eliminates arcing, switch life is longer and more reliable.

This switching performance is possible because of the excellent electrical characteristics of the 2N174; in particular, the high collector breakdown voltage, extremely high maximum collector current, and very low input impedance.

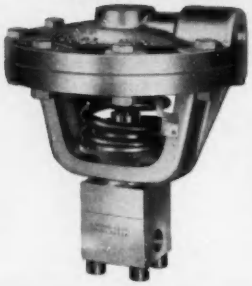
You may employ Delco 2N174 high-power transistors with confidence in their reliability and uniformity. These transistors, normalized to retain better performance characteristics regardless of age, are currently being produced by the thousands every day. Write for engineering data.

Power Switching Characteristics	
Switching Power	1000 watts
Current in "on" position	13 amperes
Input Control Power	1 watt
Power Gain	30 db
Dissipation in "on" position	8 watts
Switching time	60 microseconds

DELCO RADIO DIVISION OF GENERAL MOTORS KOKOMO, INDIANA

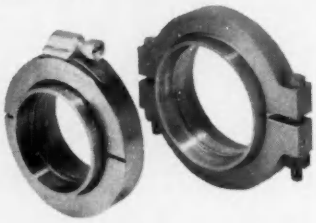
MINIATURIZATION

From Pilot Plant to Process



♦ "BANTAM" 500 SERIES

Throttling "Bantam" Diaphragm Control Valves for all standard control valve uses, Cv of 0.6 and below, up to 1000 psi and 500°F, characterized, renewable trim, 316 stainless steel and teflon only wetted surfaces, low in hysteresis, size and weight, a modern design of control valve. 2000 series "Bantam" Control Valves available for on-off service.

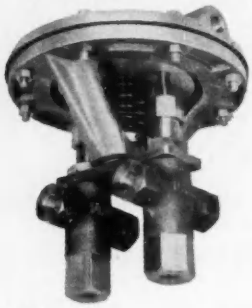


TUBE AND PIPE CONNECTORS ♦

For use in such systems as aircraft or marine applications where weight is a factor, these connectors replace standard flanges. Available in various materials, in male or female socket or butt weld design, for tubing, and up to schedule 40 pipe.

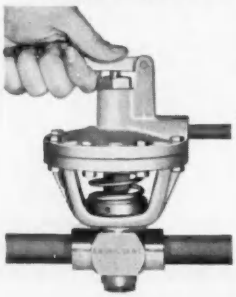
♦ "DEMI" PACKLESS VALVES

For services when packing is a problem, manifolding of small valves in one unit, these low cost valves have a great popularity. For services up to 1500 psi and 500°F., screw, toggle, or diaphragm operated, the "Demi" line is ideal for panel mounting up to five valves in one block.



WHIFFLETREE OPERATOR ♦

Two valves operated simultaneously by one operator. Valves may be globe or three-way and have a multitude of piping arrangements for mixing and routing applications.



♦ MANUAL RESET

Wherever control air on dangerous or toxic process flows must be blocked for safety, on air failure until manually reset, these valves insure against disaster. Standard sizes ¼" and ½" I.P.S.

SAUNDERS VALVES — AIR OPERATED ♦

Plastic valves, 2" and below, metal valves 1" and below, G. W. Dahl Company, Inc. diaphragm operators on these valves provide simple, sure automatic operation. Each application must submit full flow information.

Write us for complete technical information, or the address of our representative in your area.

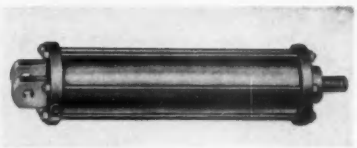
George W. DAHL Company

BRISTOL, RHODE ISLAND

reduce drift and assure longer life. Voltages begin at 25 to 75 volts and rise in 50-volt steps to a range of 350 to 400 volts. Regulation is within 0.5 percent on standard models, within 0.1 percent on precision models. Electronically regulated, these units have fast transient response and low ripple. —Universal Electronics, Santa Monica, Calif.

Circle No. 34 on reply card

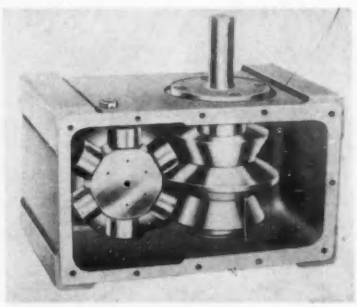
FINAL CONTROL ELEMENTS



AIR CYLINDER

Designed for long life under severe conditions, these air cylinders feature a capsule-type, alloy-steel gland, and cadmium-plated heads, clevises, and pistons. Operating pressures are 150 psi air and 500 psi hydraulic.—Densmore Engineering Co., Inc., Compton, Calif.

Circle No. 35 on reply card

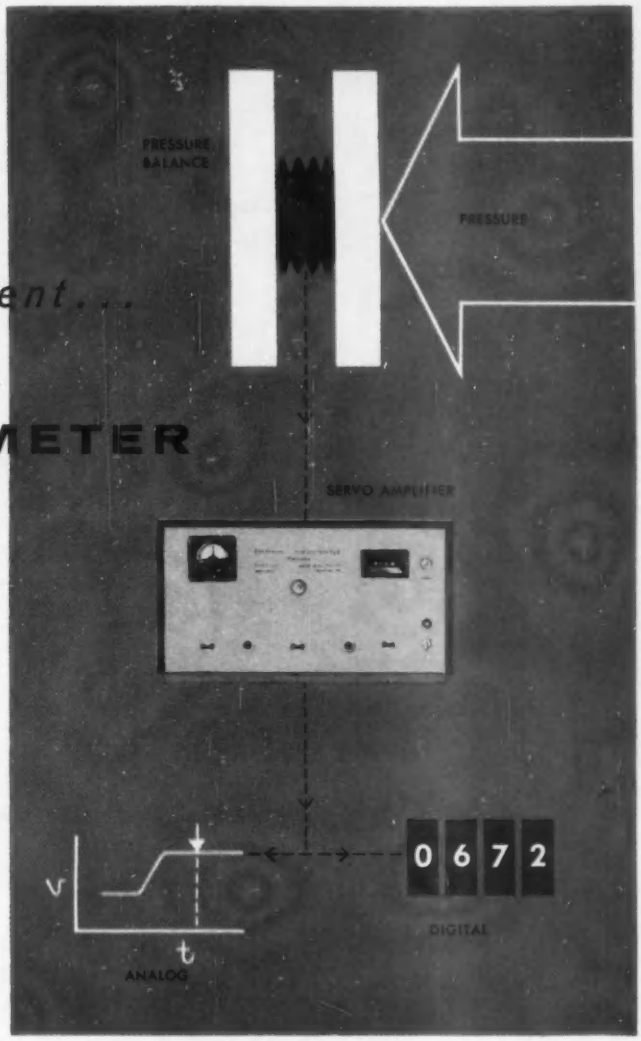


ROLLER GEAR DRIVES

Illustrated is a six-stop indexing mechanism, one of a brand new series. Rated at 2,000 indexes per min, these units are especially designed for packaging, photographic, and instrumentation. They feature a precision-cut, hardened-tool steel cam with a tapered rib and a hub with standard bearing

New standard
in pressure measurement...

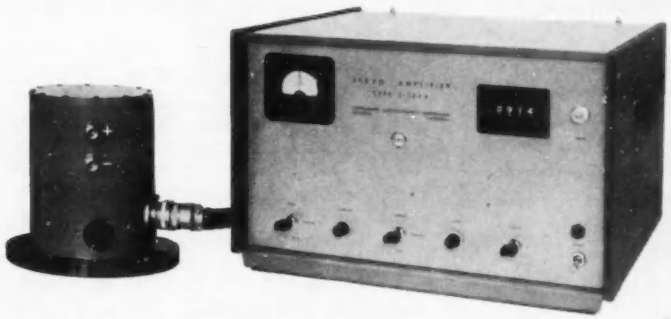
Consolidated's
ELECTROMANOMETER



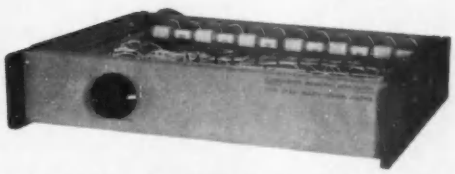
SPEED AND VERSATILITY—Now you can get high-accuracy pressure measurements where readings with mercury manometers are impractical. Compact, portable, and ruggedly built, the Consolidated Electromanometer is easy to operate and particularly useful where a large number of pressure measurements are required in a limited period of time...

HIGHEST ACCURACY—Operator error is practically eliminated with a large visual digital readout (registering ±1000 counts full-scale). An electrical analog output is provided for recording or control purposes (±10 volts d-c full scale). Linearity and hysteresis errors on the analog output are less than 0.05% of full scale.

BEFORE YOU INVEST IN ANY SYSTEM, be sure to write for Bulletin CEC 1547-X31, or contact your nearby CEC field office for complete specifications.



Designed for absolute, differential, and gage pressure measurements, CEC's Electromanometer is an electronic null-balance servo-type system consisting of a Pressure Balance and Servo Amplifier assembly with a rapid response time.

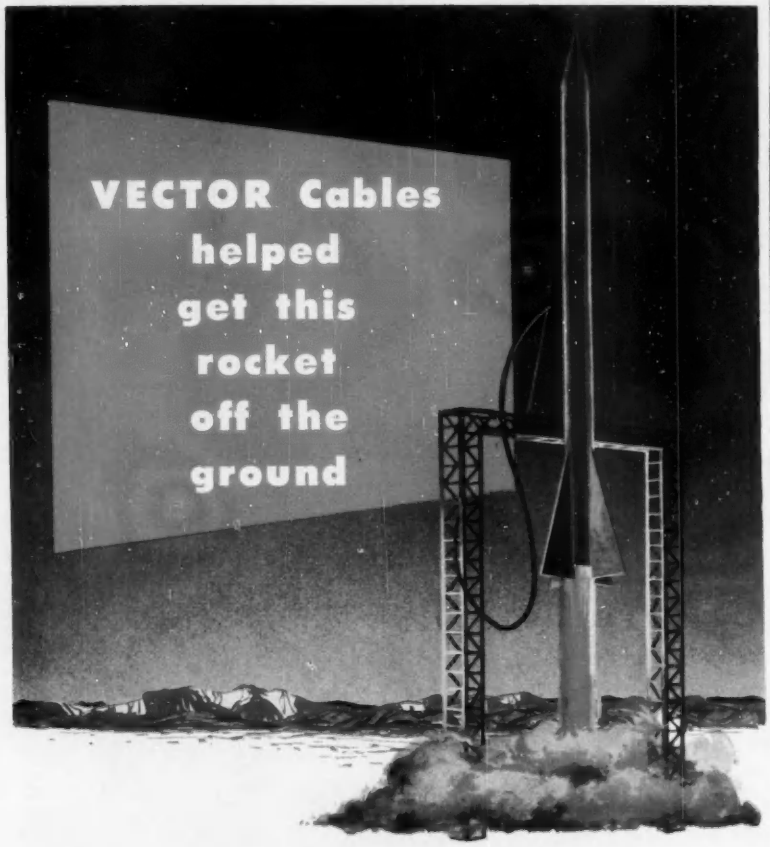


MULTI-CHANNEL ADAPTER, fundamentally a switching device, permits the use of up to six different Pressure Head assemblies with a single Servo Amplifier. The Adapter contains all necessary calibrating and balancing controls, and becomes the base for the Servo Amplifier

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

NATIONWIDE COMPANY-OWNED SALES & SERVICE OFFICES



In the overall picture of a rocket launching, a cable may appear to be a rather small detail, but as every design engineer knows, the success of the project depends on the inter-connecting cable system . . . and here's where the value of Vector's engineering staff and modern manufacturing facilities have been established.

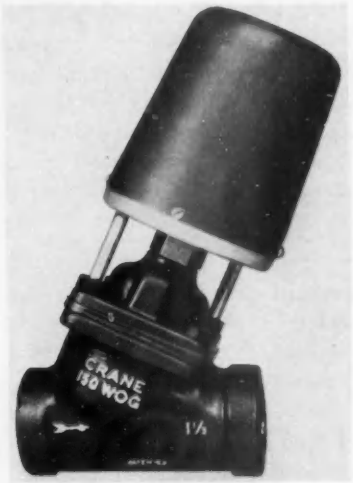
Vector has been serving the electronics industry for more than ten years . . . with custom-designed cable assemblies that range from only a few feet in length to more than a mile, and with up to 130 concentrically laid conductors. Today, more than 41,000,000 feet of Vector cable are in use under the severest conditions imaginable. They are sheathed in continuously extruded rubber, neoprene, or thermoplastic jackets which enable them to withstand extreme temperatures, constant handling and flexing, and even towing stresses.

Contact one of our representatives today. Whatever you're designing . . . if there's an interconnecting cable problem involved, Vector will supply a custom-designed cable system guaranteed to meet your requirements.

Vector MANUFACTURING COMPANY
5616 LAWNDALE AVE. • HOUSTON 23, TEXAS

followers. As the cam rotates, a curved portion of the rib indexes the hub and output shaft. When the followers reach a straight section of the rib, dwell occurs and the hub is locked with a precision of 0.001 in. and zero backlash. A modified trapezoid acceleration characteristic assures smooth, vibration-free indexing.—The Ferguson Machine Corp., St. Louis, Mo.

Circle No. 36 on reply card



ELECTRIC CONTROLLER

Designed for mounting directly on the valve stem, this new all-electric rotary-valve controller provides remote or automatic valve operation with proportional or on-off action. The Valvetrol is a self-contained gearmotor with hollow output shaft to receive the valve stem. Stem diameters from ¼ to 1 in. can be accommodated. A built-in potentiometer providing remote indication of valve position can also be used as part of a balanced-bridge control. Standard accuracy is within 1/5 of 1 percent, but accuracies to within plus or minus 1/25 of 1 percent are also possible. Selective gear ratios adapt the unit to valves having anywhere from 1/6 to 40 turns to full open.—The Jordon Co., Inc., Milwaukee, Wis.

Circle No. 37 on reply card

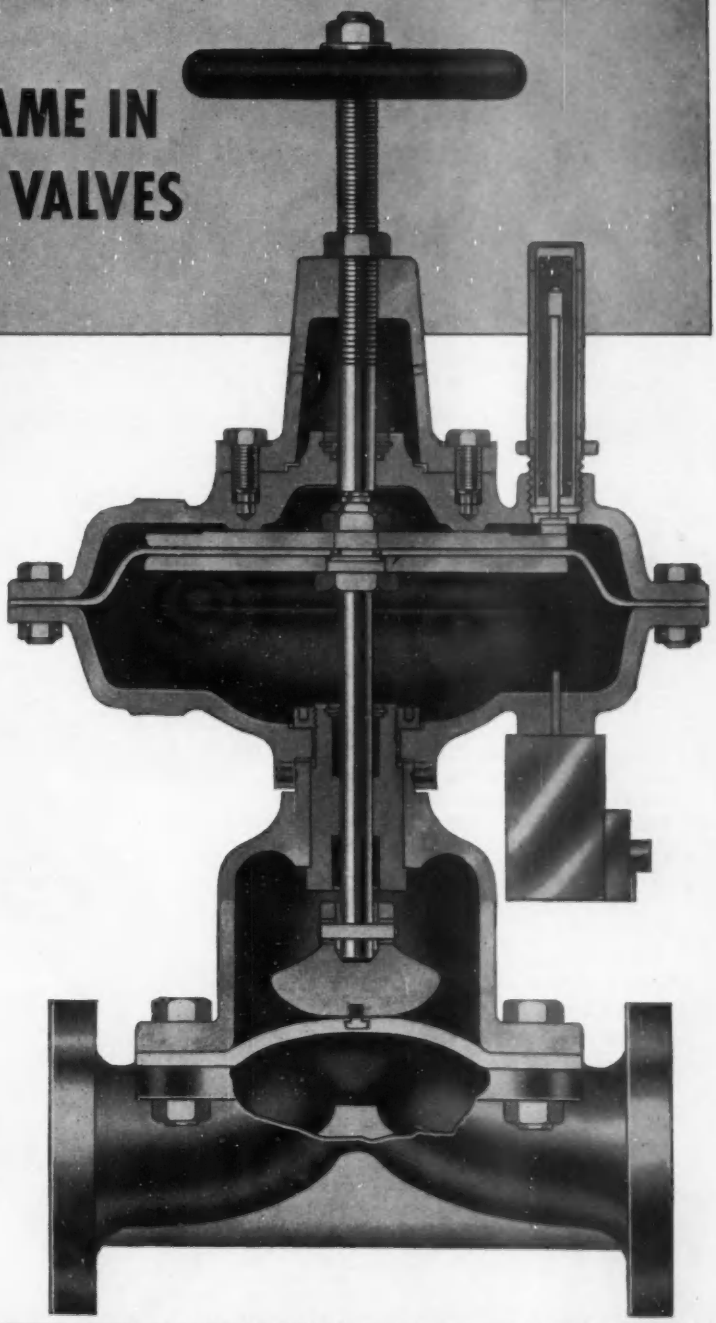
FRACTIONAL HP

A new line of lightweight, fractional-hp dc motors operates on 26 volts,

CONOFLOW...

THE FIRST NAME IN AIR OPERATED SAUNDERS VALVES

THOUSANDS IN USE IN LEADING COMPANIES



When you specify Conoflow Air Operated Saunders Valves your confidence is affirmed by thousands of successful installations. Many Conoflow Saunders Valves have been in constant, 24-hour-a-day service, year in, year out, requiring little or no maintenance.

When you specify Conoflow Close-Coupled Saunders Valves you know that you are getting the benefit of more years of experience in this line than any other valve manufacturer can offer. This *extra* engineering "know-how" enables Conoflow to provide:

- Valves in *all sizes* for both *on-off* and *throttling* control—with many original and time-proved optional features.
- Wholly integrated design—*complete valve assembly* made at the Conoflow factory by experienced men.
- Highest quality construction materials —the *right* material for the *right* job.
- Positive performance—every unit *completely tested* for dripless shut-off and peak operating efficiency before shipment.

When you specify Conoflow Saunders Valves you are certain that you are getting the *best* Saunders valve available . . . and at a *competitive price*.

WRITE FOR NEW BULLETIN HB-6 DESCRIBING THE COMPLETE LINE OF CONOFLOW SAUNDERS VALVES. IT WILL BE MAILED PROMPTLY.

Cono Controls®

CONOFLOW CORPORATION
2100 ARCH STREET, PHILADELPHIA 3, PA.

SUBSIDIARY OF WALWORTH

FOREMOST IN FINAL CONTROL ELEMENTS

CC705

HOW TO

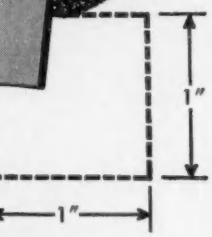
CONTROL MORE THAN

7,000 functions

IN THIS CONFINED AREA

with **3** dimensional

CAMS



Yes, in less than one square inch, about the area of an ordinary postage stamp, the output of the Parker 3 D cam can be expressed as a dependent variable . . . the resultant of two known independent variables which can produce precision functions in split seconds!

$$z = f(xy)$$

where z is the output of the 3 D cam; *x* and *y* are the two known variables.

These functions transferred through a follower assembly can activate:

AIRCRAFT—Jet Fuel Injection, Missile Control, Navigational Control, etc.

MACHINE TOOL—Automation Functions Repetitive Production, Feed Back Functions, etc.

COMMERCIAL—Pre-computed Functions Stored Information, Mental-Mechanical Functions, etc.

by Parker

Send today for FACT FILLED brochure—"3 Dimensional Cams." See how Science SAVES SPACE, produces MECHANICAL SOLUTIONS IN SECONDS!

THE PARKER-HARTFORD CORPORATION

CAM DIVISION

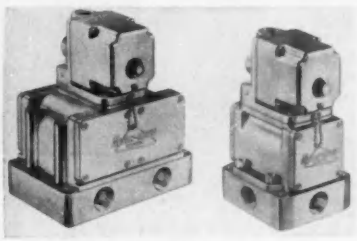
FRANKLIN AVENUE • HARTFORD, CONNECTICUT

by Parker

NEW PRODUCTS

ranges from 1/20 to ½ hp, and features electromechanical brakes, integral radio noise filters, and a new brush-rig construction. Weights range from 15 to 22.5 oz.—Lundy Mfg. Corp., Long Island City, N. Y.

Circle No. 38 on reply card

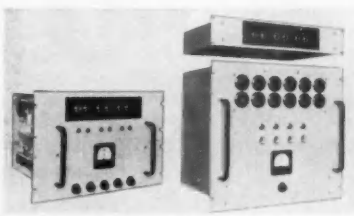


FOR AIR CONTROL

These new Nopakmatic poppet-type air-control valves automatically select pilot-air-pressure supply from an inlet port without reassembly of parts. Pilot heads are completely interchangeable, as are many other parts, thus minimizing valve and parts inventory. Valves are available for pressures to 150 psi, for 2-, 3-, and 4-way operation, and with ports to accommodate ¼-in. to ¾-in. pipe.—Galland-Henning Nopak Div., Milwaukee, Wis.

Circle No. 39 on reply card

DIGITAL DEVICES



FOR RAPID ACCESS

A digital timing generator and magnetic tape search unit now provide high-speed access to selected data in Ampex recorders and similar multichannel magnetic tape instrumentation systems. The generator puts out numerically coded timing signals, which are recorded on the tape

...directed by

the achiever!

X MINUS 5...4...3...2...1...LAUNCH! HEADED FOR ITS TARGET WITH PINPOINT ACCURACY, THANKS TO AC!

As the fire control officer calls off the seconds before touching the button sending another missile on its way, a new and remarkable device stands ready to take over.

The ACHIEVER—new inertial guidance system built by AC—brings fantastic new accuracy to the ballistic missile field. The "brain" of this wonderful new device is a new-type gyro stabilization of almost unbelievable precision ... so precise, in fact, that thousands of miles of guided flight can be achieved with uncanny accuracy.

The Achiever is a phase of AC's work as a prime contractor on guidance in the Air Force Ballistic Missile Program.

GM

AC

THE ELECTRONICS DIVISION OF GENERAL MOTORS
FLINT, MICHIGAN • MILWAUKEE, WISCONSIN

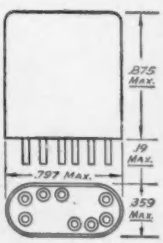
ELGIN'S NEW **MV**

Big Relay Performance!

...crystal can size

Elgin's new MV rates superior to other high performance relays, yet is less than an inch long and weighs less than half an ounce. It meets military specifications and is designed for continuous use in the —65°C to 125°C temperature range. The MV has a life rating of 100,000 operations minimum at rated load. This new relay is in production now and prompt delivery is assured. For computers, control systems and every installation that requires dependable performance AND miniature size . . . specify MV.

SPECIFICATIONS



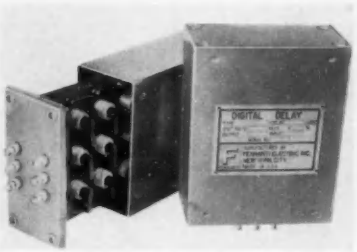
VIBRATION	10 to 80 cycles per second at maximum excursions of .06"—80 to 2000 CPS 20G's acceleration
SHOCK	50G for 11 milliseconds
LIFE	100,000 operations minimum at rated current
AMBIENT TEMPERATURE RANGE	—65°C to 125°C
DUTY	Continuous
OPERATING POWER	Nominal 1.2 watts at ambient temperature
CONTACT ARRANGEMENT	DPDT (2 Form C)
CONTACT RATING	2 amps resistive at 32VDC or 115VAC
CONTACT MATERIAL	Silver-Magnesium-Nickel Alloy
CONTACT RESISTANCE	.05 ohms
OPERATING TIME	5 milliseconds maximum at nominal power
RELEASE TIME	5 milliseconds maximum
ALTITUDE	Voltage breakdown of relay is 1000 Volt AC to 40,000 ft.—550 Volts AC to 70,000 ft.
DIELECTRIC STRENGTH	1000 volts RMS
INSULATION RESISTANCE	100 megohms minimum at 125°C
STANDARD COIL RESISTANCES	30, 120, 600, 1000, 2500, 5000, 10000 ohms, others available
SIZE	.875 high x .797 wide x .359 thick max.
WEIGHT	0.45 ounces (max.)
MOUNTING ARRANGEMENT	Bracket, side studs, top studs
TERMINAL ARRANGEMENT	Plug-in, solder-hook, 3-inch leads

ELECTRONICS DIVISION
ELGIN NATIONAL WATCH COMPANY
107 National Street, Elgin, Illinois
2435 N. Naomi Street, Burbank, California

NEW PRODUCTS

throughout the recording periods to provide a precise digital index in terms of elapsed time. The search unit operates during data-reduction periods, and automatically locates and selects for controlled feedback the tape data included between preselected time signals.—Hycon Eastern, Inc., Cambridge, Mass.

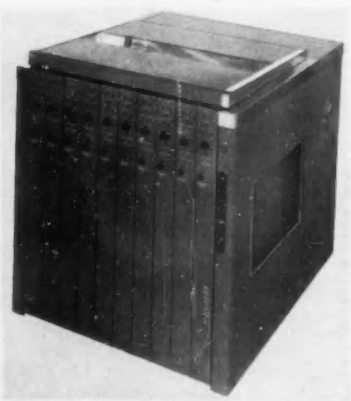
Circle No. 40 on reply card



FOR DIGITAL STORAGE

Here is a novel lumped-constant electromagnetic network specifically developed and designed for digital storage. Using only 1.2 elements per bit, it provides highly-stable characteristics without extreme tolerances on the individual elements. Hermetically sealed units can be supplied for any capacity up to 30 bits at digit rates up to 5 megacycles, and for operation at temperatures from minus 20 deg C to 70 deg C.—Ferranti Electric, Inc., New York, N. Y.

Circle No. 41 on reply card



TAPE HANDLER

Model 3219 Magnetic Tape Multiple Bin Handler will store over 160 mil-

Sensitive, Rugged, Fast . . .

the *ElectroniK* Null Indicator has easy readability

THIS completely electronic instrument has a big, clearly legible scale that reduces the chance of error. There's no need to shade the dial—it's easy to read in any light. And a handy leather grip makes it easy to carry from job to job.

It's sensitive enough for all electrical bridge measurements. And it's rugged enough for production line work. It's fast, simple, compact. It withstands vibration and shock . . . needs no special mounting, no leveling.

Heavy overloads won't damage it. There's no "loss of spot" when excessive signal is applied; you always know which direction to go for bridge correction.

The modern successor to the galvanometer, the *ElectroniK* Null Indicator is available for immediate delivery. The price is $175.00, f.o.b. Philadelphia. Order today—and put new convenience in your own test work!

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

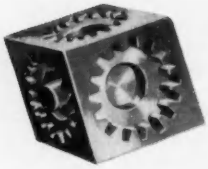
● **REFERENCE DATA:** Write for Data Sheet 10.0-12.

COMPARE THESE SPECIFICATIONS

Period—less than ½ second
Current Sensitivity—.001 microamp/mm.
Voltage Sensitivity—1 microvolt/mm.
Input Impedance—1000 ohms at max. sensitivity
Overload Rating—1 volt at max. sensitivity
Stability—less than 1 mm. zero shift/hour
Damping—critically damped; independent of external resistance
Terminals—input and ground; for spade, pin or banana plugs
Power—115 volts, 60 cycles
Scale Markings—
−1 to +1 in mm. } over 2½" radius
−4 to +4 in cm. }
Dimensions—17⅛" long x 5⅜" wide x 7¾" high
Weight—15 lbs.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

THE DIE IS CAST *PERFECTLY EVERYTIME*



Servotherm® Pyrometer Systems Remotely Control Temperatures to ±1% and Respond Within 250 Milliseconds

In die casting and molding processes, Servotherm Pyrometer Systems remotely measure and control such factors as: temperature of dies and molds, temperature of castings, and surface temperature of the melt. Accurate control of these factors is vital in obtaining better castings while drastically reducing rejects.

Control of critical temperatures must be achieved, in most primary metal processes, without direct contact. Remote detection, plus fast response, accurate sensitivity, portability, and the opportunity for continuous recording make Servotherm Pyrometer Systems ideal for these typical process applications:

- steel tube moving through annealer
- rod and tubing being drawn or rolled
- steel strap in continuous processing furnace
- steel hardening process
- determining melt temperature of alloys

Servotherm Pyrometer Systems solve production problems wherever temperature measurement and control is critical. Here are some of the industries using Servotherm Systems to solve their production problems.

- Fabricated Metals
- Ceramics and Glass
- Plastics
- Machinery
- Textile
- Paper and Printing
- Lighting and Power
- Rubber and Petroleum Products

For more information on Servotherm Pyrometer Systems, use your company letterhead to request TDS-IRPSA.

If you have a temperature measurement or control problem, our Infrared Applications Engineering Staff is always available to consult with you.

lion bits and can be used for sequential sorting or as a random-access memory of high capacity. It consists of 10 separate bins, each with a storage capacity of over 8 million bits (a bin normally contains 500 ft of 1-in. tape for 14-channel recording with 200-ppi density). Each bin has its own record-playback head, which may be relay-switched to a common output. Using the digit-by-digit method with a simple counter and matrix, decimal sorting rates up to 100 information blocks per sec are achieved. —Potter Instrument Co., Inc., Great Neck, N. Y.

Circle No. 42 on reply card

COMPONENT PARTS

AC MOTOR GENERATOR

A size-10 ac motor generator, recently put into production, features minimum length and weight, and a cast rotor construction. The unit is well suited for error rate damping in servo systems. Motor characteristics include a main-phase voltage of 26 volts, 400 cps, a control-phase voltage of 0 to 26 volts, a no-load speed of 7,000 rpm, and a stall torque of 0.33 oz-in. Generator has a main-phase voltage of 10 volts, 400 cps, an output of 0.16 volts per 1,000 rpm, and requires 0.2 watt input power.—Clifton Precision Products Co., Inc.

Circle No. 43 on reply card

For

ACCURATE HIGH SPEED SWITCHING..

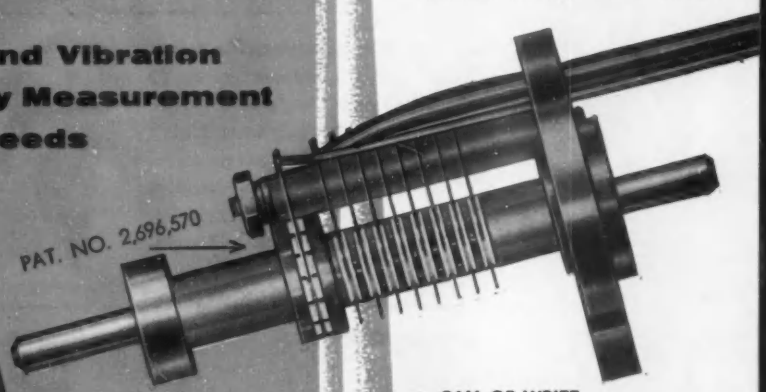
Specify

ELECTRO TEC

miniature ultra-low torque Precision Selector Switch

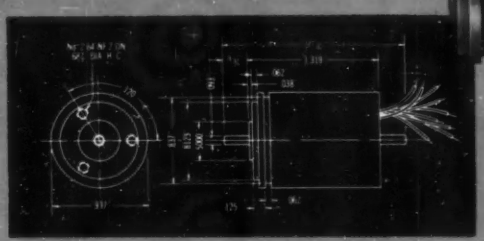
- **Withstands Shock and Vibration**
- **Offers High Accuracy Measurement**
- **Operates at High Speeds**

This new Electro Tec Precision Selector Switch is ideal where miniature size, low friction torque, high accuracy, and low electrical noise at high speeds are requirements. Simplified circuits and long service life recommend it for a wide variety of uses including sampling, pulse generation for precision measurement, telemetering and strain gage applications, in aircraft, missiles, servos, computors, etc. Switch design incorporates many exclusive features that have gained industry-wide acclaim for Electro Tec precision slip rings, commutators and brush blocks.



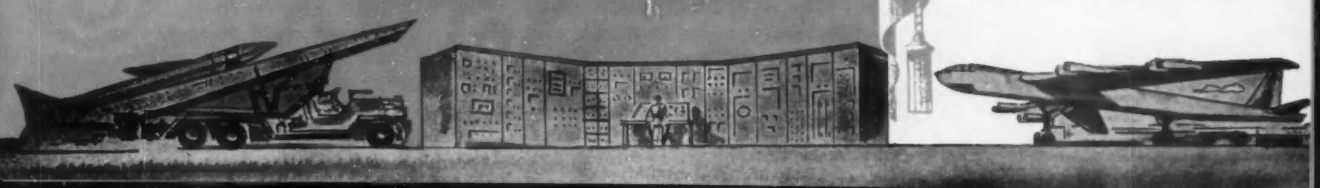
CALL OR WRITE FOR ILLUSTRATED BROCHURE

8 or 10 position switches in standard size 10 synchro housings are available for immediate delivery; other circuit combinations supplied to specifications.



Electro Tec Corp.

SO. HACKENSACK
NEW JERSEY
Tel.: HUbbard 7-4940



WHAT'S BEHIND THE SIGMA SERIES 72 TELEGRAPH RELAY ?

The "72", as a polarized relay particularly suited to telegraph use, offers a combination of extremely worthwhile operating features. Among them are 500 pulse-per-second speed, freedom from maintenance for at least a half a billion operations (60 ma. 120 VDC inductive load), adjustable bias and sensitivity.

In addition, the usefulness of 72's in telegraph service is also substantially increased by the following three related items:

STANDARD REPAIR KIT for the 72 contains normally (and easily) replaceable parts: two contact screws and one ferro-nickel armature.

MAINTENANCE AND ADJUSTMENT MANUAL for the 72 describes in detail all service operations likely to be needed in the field. What and what not to do, and the appropriate methods, are comprehensively set forth and illustrated in 18 pages. Available to 72 users.

MODEL 4501 TEST SET permits thorough operational checking and adjustment, using either or both coils, of the relay under test.* Measures operating ("trip") values (either manually or automatically), bias, percent-break, and insulation. Provision is also made for connecting an external drive directly on relay coils, and 'scope connection for observing contact performance in bias and percent-break tests. Standard relay rack panel mounting, 5¼" high, less than 6" deep. Case, socket adapters and instruction manual included.

*The Test Set is simply a useful —but not vital— accessory to telegraph relay use. It performs the described tests on not only the Sigma Series 72 relay, but on our Series 7, the WE 255A (which our 72AOZ-160 TS can replace), the WE 215, and similar relays.

SIGMA

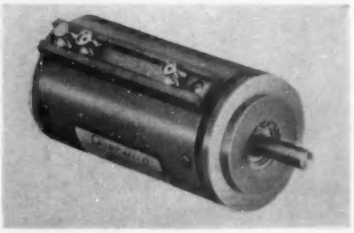
SIGMA INSTRUMENTS, INC.
69 Pearl St., South Braintree 85, Mass.

NEW PRODUCTS

SUBMINIATURE POT

Said to be ideal for hydraulic-valve or other short-stroke applications, this 1-oz rectilinear pot is only 1.4-in. long. Resistance of both elements is 1,000 ohms, plus or minus 5 percent, linearity is within 0.75 percent, and resolution is down to 0.002. Both elements are center-tapped and each has a power dissipation of ½ watt. Features include a precision-cast case, glass-seal terminals, stainless-steel pushrod, and 100-percent bonded construction. —Humphrey, Inc., San Diego, Calif.

Circle No. 44 on reply card



TEN-TURN POTS

Two new 10-turn potentiometers, the Type 907 Phenolic and the Type 908 Metal Case, feature resistance ranges of 100 to 100,000 ohms, and 3,600 deg of electrical rotation. Type 907 has a linearity range of 0.1 to 0.5 percent, while Type 908 is linear to within 0.05 to 0.25 percent. A special long-life feature has been incorporated in the latter. The mechanical drive in this unit is separate from the helical coil of resistance wire, thereby eliminating wear on the coil. The wiper is guided on the wire by a tab that slides in a groove parallel to the winding. Both types have a temperature range of minus 55 deg C to plus 85 deg C. —Components Div., Fairchild Controls Corp., Hicksville, N. Y.

Circle No. 45 on reply card

"re: *Your shipment on the 5th...*"

Some people still send communications one character at a time.

Others use DATAFAX—the fast Stewart-Warner electronic way to transmit all data over telephone lines.

Datafax transmits and records any material: correspondence, drawings, pictures, printed matter, even handwritten notes. And since copies are exact duplicate images of the original, chance for error is eliminated.

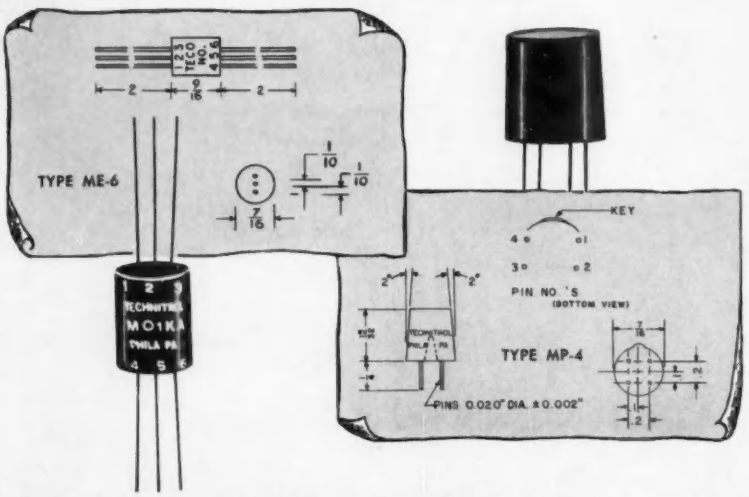
Cost?

Automatic transmission and recording eliminate need for full-time operator; recorders will even respond to transmissions sent after the office is closed for the day. Datafax also eliminates retyping, proofreading, intermediate handling, intransit delays—and their clerical costs. The clear, smudge-proof, permanent Datafax copy costs less than 2¢ for a letter-sized unit.

Chances are your accounting . . . inventory control . . . engineering . . . production . . . branch sales . . . and warehouse operations have outgrown Primitive Communications. If so, you'll want to find out about Datafax. First, send for your copy of the free Datafax bulletin. Write: Stewart-Warner Electronics, Dept. 23, 1300 N. Kostner Ave., Chicago 51, Ill.

STEWART SW WARNER ELECTRONICS
a Division of Stewart-Warner Corporation

TRANSFORMERS
by TECHNITROL



Wound on ferrite cores, the Type M series is available in a variety of windings to cover pulse widths from 2 microseconds down to .05 microsecond, wound inverting or non-inverting.

While the M series is particularly adapted to subminiature and transistor circuits, we design and build pulse transformers to fit specific circuits or to meet definite mechanical or thermal requirements, including MIL-T-27A.

Additionally, Technitrol makes a complete line of lumped and distributed parameter Delay Lines and a variety of electronic test equipment.

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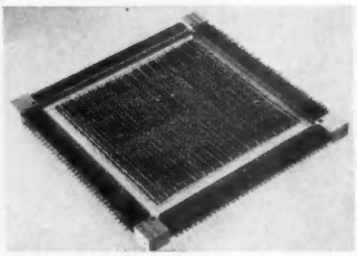
ENGINEERING COMPANY
1952 E. Allegheny Ave., Phila. 34, Pa.

NEW PRODUCTS

SERVO DAMPERS

A simple way to obtain high velocity and torque constants in instrument servos is provided by the Model CD-60 servo dampers. These viscous-coupled-inertia dampers mount directly on either end of Diehl FPE-25, 5-watt servomotors, thus eliminating the need for tachometers, networks, or other bench-engineered means of stabilization. Units are factory-adjusted to specified time constants within the range from 0.02 to 1.20 sec. Mounting styles are available for tapered shafts or straight shafts with or without integral pinion.—Feedback Controls, Inc., Waltham, Mass.

Circle No. 46 on reply card



MEMORY PLANES

An improved design gives these new magnetic-memory planes greater frame strength and rigidity. It permits the frames to be assembled individually in stacks, eliminating the need for molds. Frame sizes range up to 10 by 10 in. Spacers are not required for the vertical assembly of the planes, since the four corners are made deeper than the rest of the frame. Other advantages include faster delivery and the elimination of tooling charges.—General Ceramics Corp., Keasbey, N. J.

Circle No. 47 on reply card

OSCILLATOR

A new subcarrier telemetering oscillator, now in production, has been designed for increased reliability, accuracy, and flexibility. Linearity is better than 0.5 percent of full bandwidth over full input range. A 1-volt B-plus variation produces less than plus or minus 0.5 percent full-bandwidth-frequency deviation; a plus or minus 5 percent filament voltage variation produces less than 1 percent

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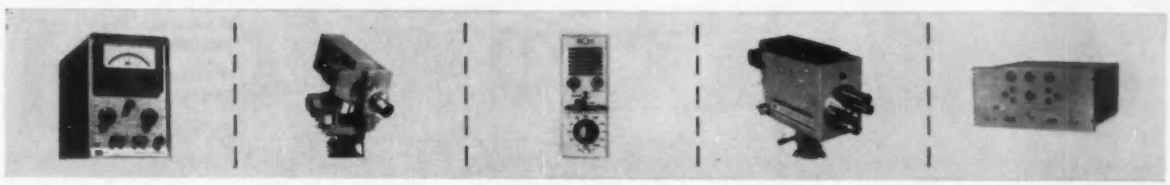

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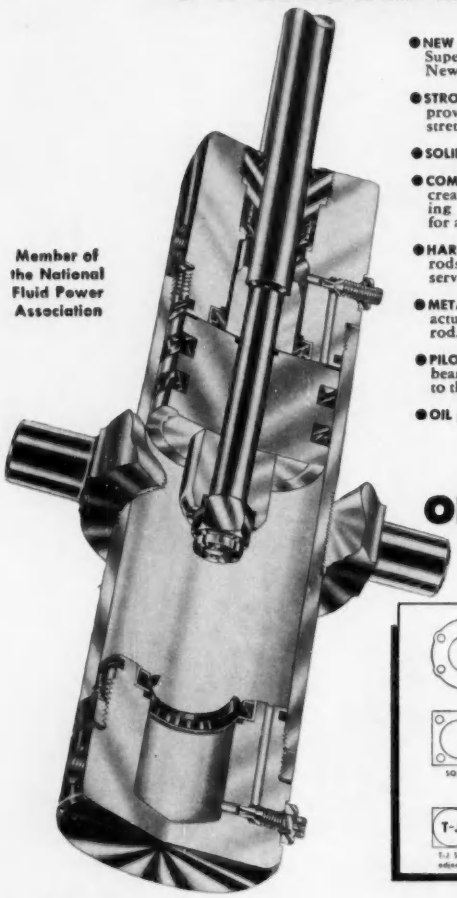
T-J Spacemaker CYLINDERS



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- **STRONGER** than outmoded tie rod design, proven through actual tests. No tie rods to stretch.
- **SOLID STEEL HEADS** throughout the full line.
- **COMPACT DESIGN** eliminates tie rods, increasing the strength and reducing mounting space required, providing extra room for adjacent equipment.
- **HARD CHROME PLATED** body bores and piston rods . . . assure you of long trouble-free service. (Standard at no extra cost.)
- **METALLIC ROD SCRAPER**, not just a wiper, actually removes foreign matter from the rod.
- **PILOTED PACKING GLAND** with extra long bearing. Additional strength and support to the piston rod.
- **OIL** pressure to 750 p.s.i. AIR to 200 p.s.i.

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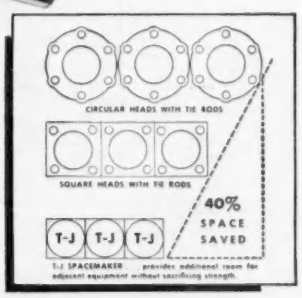
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SQUARE HEADS WITH TIE RODS
40% SPACE SAVED
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T-J SPACEMAKER . . . provides additional room for adjacent equipment without sacrificing strength

You *save 40% space* when you switch from outmoded tie rod cylinders to the T-J Spacemaker! It's stronger, too! Fits right into automation programs in countless plants. Delivers top performance and dependability with a big *plus* in advanced features. Wide range of styles, capacities . . . reduces man-hours and costs in all kinds of push-pull-lift jobs. Off-shelf delivery in 64,000 combinations!

NEW LITERATURE—Send today for new Catalog SM56 with complete engineering details on Spacemaker line. Write The Tomkins-Johnson Co., Jackson, Mich.

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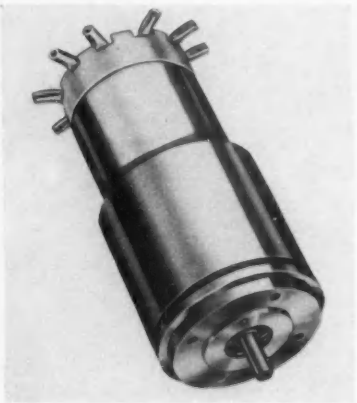
NEW PRODUCTS

full-bandwidth deviation. Plug-in printed-circuit filter board permits changing frequency channel of the basic oscillator without removing it from service.—Dorsett Laboratories, Inc., Norman, Okla.

Circle No. 48 on reply card



MOTOR-GENERATORS

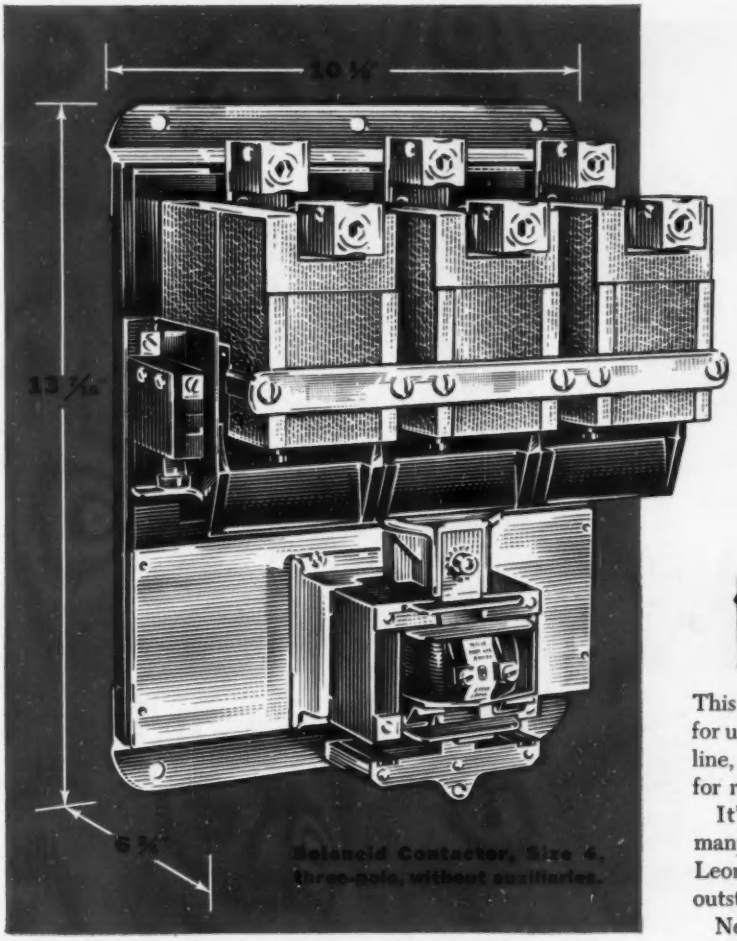
Size 18 servomotor-rate generators are now available from this manufacturer. The 20-oz, servo-mounted units consist of a servomotor and rate generator housed in a stainless-steel case and rotating on a common shaft. Rotor inertia is 5.73 gm cm^2. A 60-cps model features a minimum stall torque of 2.35 oz-in. and a stall acceleration of 29,000 rad per sec^2. On the 400-cps model minimum stall torque is 4.0 oz-in. and acceleration is 49,000 rad per sec^2.—Helipot Corp., Newport Beach, Calif.

Circle No. 49 on reply card

NONLINEAR POTS

A new line of precision, wire-wound nonlinear potentiometers, for sine-cosine and square-law functions, is now available. Standard units are made in AIA sizes 30 and 20. Tolerances on the sine-cosine pots are 0.5 percent peak to peak for the size 30, and 1.0 percent peak to peak for the size 20. On the square-law pots tolerances of 0.25 percent and 0.75 percent independent conformity are standard.—Ace Electronics Associates, Inc., Somerville, Mass.

Circle No. 50 on reply card



Solenoid Contactor, Size 4, three-pole, without auxiliaries.

NEW 150-amp solenoid contactor extends proven line

This new Size 4 A.C. solenoid contactor is ideal for use in motor starters and controllers for main line, accelerating and reversing purposes and for resistance heating and lamp loads as well.

It's the new Bulletin 4454—incorporating many advanced design features found on Ward Leonard's Sizes 0 to 3 contactors. Check these outstanding features:

New sintered-silver-cadmium-oxide contacts—can repeatedly handle high inrush currents without a sign of contact welding, excessive pitting or other damage.

Simple, compact solenoid design—excellent for modern metal control panels using accessible front-of-board wiring, particularly useful where panel space is limited.

Available with two or three main poles and up to 4 side-mounted auxiliaries. Also with provision for mechanical interlocking and addition of overload relays.

Completely described in Bulletin 4454. Write for your copy today. The Ward Leonard Electric Co., 9 South Street, Mount Vernon, New York. (In Canada: Ward Leonard of Canada Ltd., Toronto.) 7.6

ENGINEERING DATA

Size 4 A.C. Contactor Ratings*

Service	8-Hour Ampere Rating		Enclosed Power Rating	
	Open	Enclosed	Three Phase Volts	H.P.
Across-the-Line Starting	150	135	110 220 440-550	25 50 100
Across-the-Line Plug-Stop or Jogging	150	135	110 220 440-550	15 30 60

Service	8-Hour Ampere Rating	Single Phase Volts	Single Phase K.W.	Three Phase Volts	Three Phase K.W.
Resistive Heating Load**	150	110 220 440 550	15 30 60 75	110 220 440 550	26 52 105 130
Tungsten Lamp Lighting or Infrared Heating Load**	120 Amperes for 250 Volt Circuits or Less				

*The ratings listed are those recommended by the National Electrical Manufacturers Association.
**These ratings apply to open or enclosed contactors.

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WARD LEONARD ELECTRIC COMPANY
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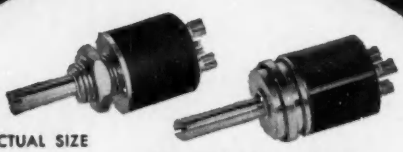
Rule-Engineered Controls Since 1892

NEW! 1/2-inch wire-wound



ACTUAL SIZE

UP TO 250 K

PRECISION POTENTIOMETERS

Now You Can specify a Waters pot for miniaturized designs that require potentiometers up to 250K. In the reliability-proved construction of the AP-½, these new, higher values give you:

- ***Resistances — 10 ohms to 250 kilohms***
- ***Ganging — up to four units***
- ***Three mounting styles — plain-bushing, split-bushing, or servo***
- ***Three terminal styles — radial, axial, or wire-lead***
- ***Automation models — for printed circuits***

General specifications: Centerless-ground, stainless-steel shaft can be sealed with 0-ring; gold-plated, fork-type terminals standard; 2% standard linearity for 50K and above — 5% for lower values; temperature range −55 to +105C, to 125C on order; 2 watts at 80C; anodized aluminum body ½" diameter × ½" long — ⅝" long for 100K and 250K; corrosion-resistant-alloy bushing; all electrical connections spot-welded or soldered; furnished with stops or for continuous rotation. *Write for data sheet on these dependable ½" potentiometers.*

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Complete new family of Waters precision potentiometers

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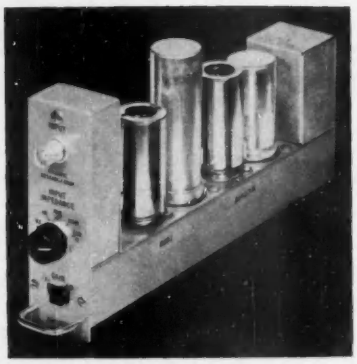
NEW PRODUCTS



COMPACT AMPLIFIER

This new amplifier, designed for laboratory applications where high input impedance and broad band response are required, is especially useful for maintaining low-frequency response and signal level of piezoelectric accelerometers, pressure pickups, and similar transducers. Unit is said to work well with ocilloscopes, tape recorders, and other measuring equipment whose load impedance is greater than 5,000 ohms. Compact design permits mounting up to ten units side by side in a special frame for 19-in. rack mounting.—Atlantic Research Corp., Alexandria, Va.

Circle No. 51 on reply card

LOW-DRIFT AMPLIFIER

Shown above is the Model 307-A low-drift dc amplifier for use with wire strain gages, transducers, thermocouples, etc. It will drive most galvanometers, including the low-sensitivity, high-frequency types, and provides excellent linearity over a wide range of input voltages. Instrument gives fine resolution with a 20-step attenuator and a unique gain control which permits full-scale galvanometer

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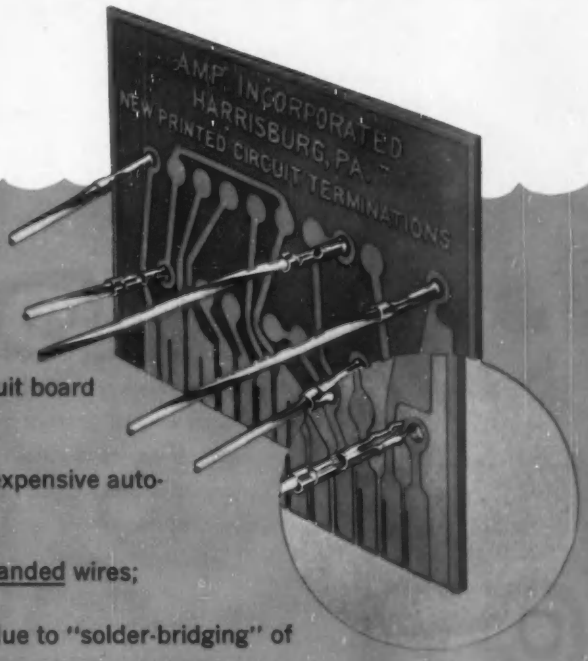
...because the NEW AMP SNAPIN



- Gets leads to the printed circuit board in one assembly operation;
- Eliminates an investment in expensive automation equipment;
- Can be applied to solid or stranded wires;
- Eliminates danger of shorts due to "solder-bridging" of insecure leads;
- Has construction details that promote good capillary flow of solder during the dipping process;
- Is self-retaining, with no damage to the printed circuit board during preassembly operations;
- Is self-aligning—no further positioning or deformation is required.

Write today for additional information on the NEW A-MP SNAPIN, *the* AMP-EDGE *Connector and other A-MP products designed for printed circuit applications.*

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A MIND OF ITS OWN

The first missile to reach the moon will be equipped with its own electronic brain – a compact visual computer, occupying not much more than half a cubic foot of precious room, that will mastermind the incredibly complex operations of man's first venture into outer space. With respect to earth coordinates, such a flight control system must continuously measure the rocket's position and velocity with surpassing speed and accuracy: tolerances of a fraction of a mil in angular resolution and of a small fraction of a mile per second will have to be maintained in order to land within a ten-mile radius on the lunar surface. To effect precise and rapid corrections in vector thrust, the computer must be capable of making thousands of calculations per second and storing within a memory the size of a ping-pong ball thousands of "bits" of essential information. Microminiature minds for moon-bound missiles are only one fascinating field of investigation at Systems Laboratories, the first corporation in the world to specialize in the research and development of interplanetary travel. If you are a scientist or engineer who would like to take part in the greatest adventure of our time a note to Dr. John L. Barnes, SLC's president, will bring a prompt and personal reply.

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NEW PRODUCTS

deflection adjustment for input voltages between adjacent attenuator settings.—Allegany Instrument Co., Inc., Cumberland, Md.

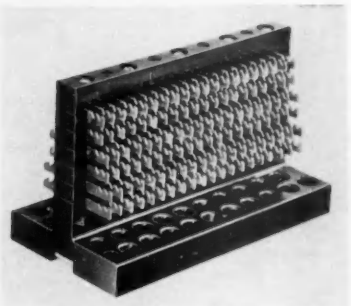
Circle No. 52 on reply card

NEW MICROPOT

A new single-turn Micropot potentiometer is now in production. Called the 910 Series, the unit is linear in function, and features high accuracy and long life. Resistance element and terminal leads are molded into a single unit for better operation under severe vibration and high-temperature conditions. The 910 has a power rating of 5 watts and a resistance range of 50 to 10,000 ohms, plus or minus 5 percent. Standard linearity accuracy is within 0.5 percent. Units may be ganged and each cup individually phased in the field. All models have ball-bearing mounted shafts.—The G. W. Borg Corp., Janesville, Wis.

Circle No. 53 on reply card

ACCESSORIES & MATERIALS

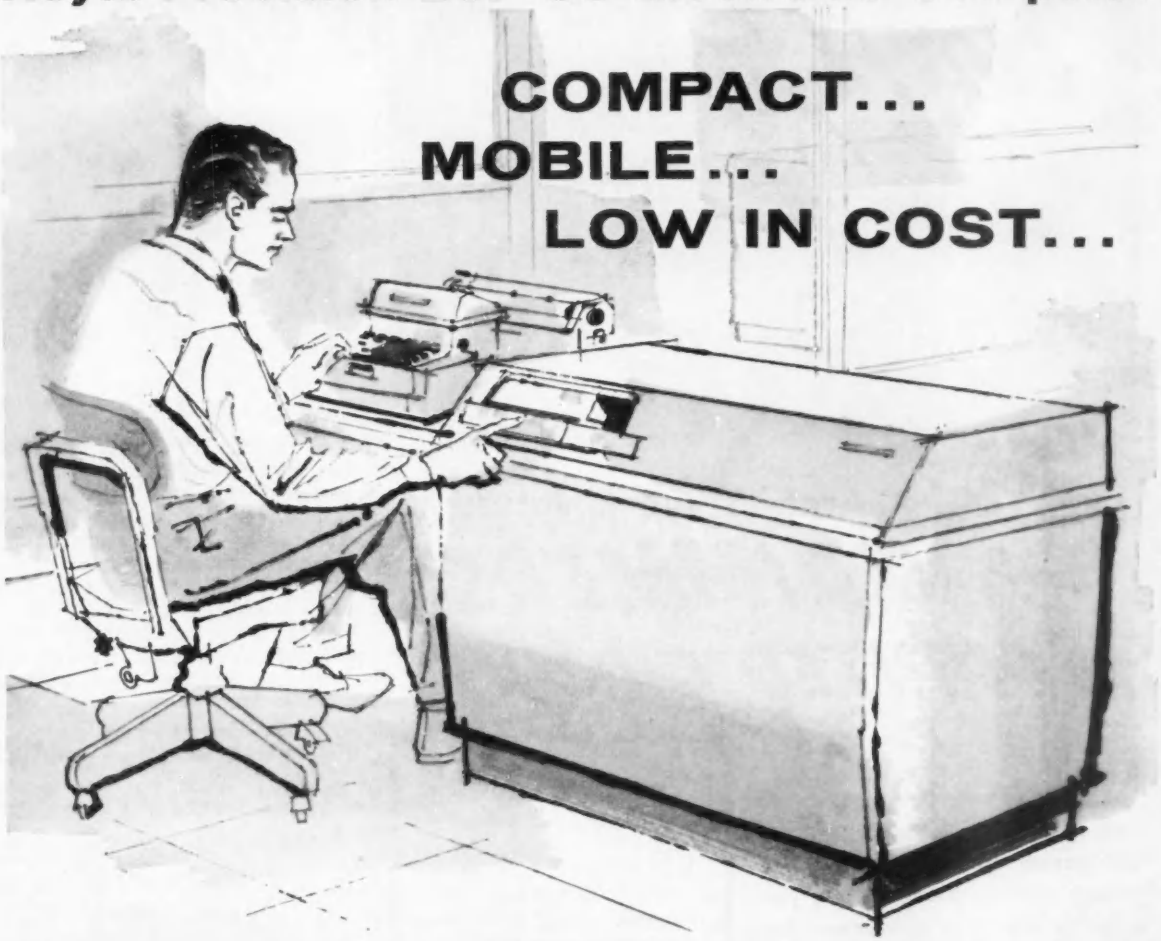


STACKED TERMINALS

Molded of a durable phenolic plastic and designed to permit stacking of as many as six rows, the PJ-106 terminal block above will provide up to 120 brass-plated terminals. Graduated in length for ease of wiring, the terminals are identified by numbers along the top row. Model shown measures 3 by 6-1/16 by 3½ in. Height varies with the number of rows required.—Audio Development Co., Minneapolis, Minn.

Circle No. 54 on reply card

Royal Precision LGP-30 Electronic Computer



high-speed computation right at your desk

The result of 20 years' experience in the design of electronic computers, LGP-30 puts you in complete control of your own engineering problems. Used right at your desk, LGP-30 allows you to program your own material without planning in detail. You modify equations on the spot, follow your work to completion. Thus, you eliminate much detailed calculation . . . uncover added time for creative engineering.

Ease of operation. LGP-30's simple command structure offers the same complete internal programming found in computers many times its size and cost. Internally binary, serial, single address . . . LGP-30 enters and reports alpha-numeric information by punched paper tape or keyboard.

Greatest capacity in price range. The most powerful stored program computer of its size yet developed, LGP-30 has a magnetic drum "memory" of 4096 words. Fully automatic, it performs sub-routines . . . executes self-modifying programs.

Exceptional flexibility. LGP-30's wide range of applications includes double precision abstractions; compiling and diagnostic routines; 3-address interpretive routine with floating point abstractions; matrix operations including inverting and Eigen value problems; basic trigonometry and log functions; square root and roots of polynomials.

Nation-wide sales and service. Detailed analysis of your requirements is available through Royal McBee's nation-wide staff of trained applications engineers.

Outstanding features of LGP-30

- **Operates from regular wall outlet (110 volts AC).**
- **No expensive installation . . . no external air conditioning.**
- **Unusually large "memory"— 4096 words.**
- **Word length: 32 bits, including sign and spacer bit.**
- **Average access time: 8.5 ms.**
- **Optimum access time: 2 ms.**
- **Lowest cost ever for a "complete" computer.**
- **Nation-wide sales and service.**

For further information, write Royal McBee Corporation, Data Processing Equipment Division, Port Chester, N. Y.

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ROYAL TYPEWRITERS • McBEE BUSINESS SYSTEMS

Acetrim* sub-miniature

precision **TRIMMERS**

for PRINTED CIRCUITS

Here is another new development from Ace . . . sub-miniature precision wire-wound trimmers especially for printed circuits. Designed and produced to meet your tightest specifications, the new Acetrim has flat or round tabs to facilitate production assembly. Just plug into printed circuit board, secure, and dip solder.

Featuring

- ½" size
- 10 ohms to 150 K
- weight ¼ ounce
- power 2 w. @ 60° C. max.
- temperature to 125° C.
- sealed, moistureproofed, anti-fungus treated
- withstands severe shock, vibration, acceleration
- meets applicable Military specs

Ace delivers reliability

Modern mass production techniques assure delivery to meet your schedules . . . rigid quality controls assure highest standards of performance-reliability.

Acetrim — *write for Technical Data Unit #563.*

Acepot — ½" sub-miniature precision wire-wound linear potentiometers from 10 ohms to 250K. ±.3% standard. *Write for Technical Data Unit #564.*

Nonlinear Acepot — precision wire-wound nonlinear potentiometers for sine-cosine and square-law functions and other applications. High resolution, close conformity. *Write for Technical Data Unit #572.*

X-500 Acepot — ½" sub-miniature precision potentiometers for extreme temperatures of —55° C. to 150° C. 10 ohms to 250K. *Write for Technical Data Unit #571.*

*trademarks applied for

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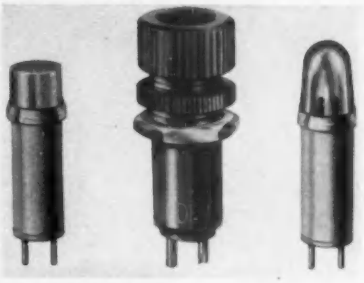
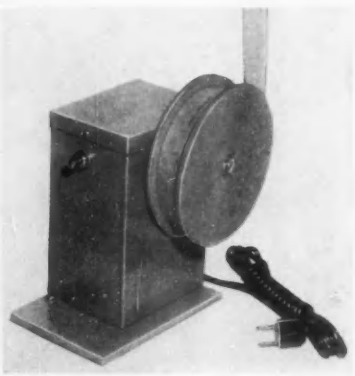


PLUG-IN LIGHT

This miniature indicator light permits plug-in replacement of a neon or incandescent lamp and requires a mounting hole of only ⅜ in. in diam. The unit is designed for aircraft instruments, computers, control systems, telemetering equipment, and other military or commercial applications where miniaturization and reliability are essential. A round-nose lens is supplied for a neon lamp, a flat-nose type for the incandescent lamp.—Eldema Corp., El Monte, Calif.

Circle No. 55 on reply card



TAPE WINDER

Shown is the Model 3055 Tape-File electric tape winder. Suitable for use in taking up tape either from a punch or reader, the unit can also be used to rewind adding-machine tapes, and is easily adapted to teletype systems. The power winder is designed to maintain a constant tension on the tape as it flows intermittently from punching equipment without damaging the tape or its own motor. Compact and portable, it will operate on any 110-volt circuit.—Dresser Products, Inc., Providence, R. I.

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(100) WIDE-BAND SCOPE. Laboratory for Electronics, Inc. Bulletin 411A, 4 pp. Leaflet describes the Model 411A oscilloscope, a wide-band general-purpose instrument for laboratory use. Gives specs on the basic unit and on six optional plug-in units that increase its versatility.

(101) PULSE CALIBRATOR. Electronic Instruments Div. of Burroughs Corp. Technical brochure describes a new instrument for measuring current and voltage pulse amplitudes, pulse durations, and rise time. Shows how the calibrator operates, illustrating and explaining actual waveforms obtained from different applications.

(102) "ELECTRON CONTROL CENTERS". Barber-Colman Co. Booklet F-8031, 8 pp. This five-color bulletin discusses the functions, uses, and advantages of centralized automatic control with visual supervision of the system.

(103) STRAIN-GAGE BALANCE. Task Corp. Brochure, 4 pp. Gives detailed information on the operation, performance, and construction of a six-component internal strain-gage balance. Also contains a size-range chart and a cutaway drawing of the instrument.

(104) ELECTRONIC SYSTEMS. Cook Electric Co. Brochure No. 1-57, 22 pp. Contains photographs and illustrations of typical projects undertaken by this company's Electronic Systems Div. These include control assemblies and complex electronic gear that can be mass-produced.

(105) PLUG-IN COUNTING CIRCUITS. Catalog No. 11437, 4 pp. Two subminiature, transistorized counting circuits are described. Actual-size photos and dimensioned drawings illustrate design and construction features, while circuit diagrams cover typical applications.

(106) REGULATED DC SUPPLY. Dynamic Controls Co. Bulletin DC T-157, 2 pp. Presents the unusual transient performance and other electrical and mechanical features of a new thyratron dc power supply. Oscillographic recording shows typical response of output voltage to step application of ac line voltage and load.

(107) METAL FILM RESISTORS. International Resistance Co. Bulletin B-3, 4 pp. Contains comprehensive data on the construction, application, and characteristics of Types MEC and MEF metal film precision resistors. Performance chart and graphs serve as handy reference.

(108) TYPICAL COMPUTER PROBLEM. Computer Div. of Bendix Aviation Corp. Application Report No. 3, 4 pp. Describes in detail how a Bendix G-15 computer saved considerable time in solving a turbine problem.

(109) CONTROL-SYSTEM ANALYSIS. Brush Electronics Co. Technical Bulletin, 8 pp. Illustrates and describes a servo analyzer for control-switch analysis work. Portable, cart-mounted, and rack-mounted models are available. Should be of interest to both design and operating engineers.

(110) LOW-FLOW METER. George Kent, Ltd. Publication 227, 2 pp. Describes the Model CM Oil Meter, a low-flow unit designed for industrial applications. Covers important features, performance, materials of construction, pipe connections, and dismensions.

(111) MAGNETIC AMPLIFIER. Magnetic Amplifiers, Inc. Form S765, 2 pp. Has a tentative data chart on the characteristics of a new miniaturized magnetic amplifier. States that these characteristics are such that ". . . a complete high performance electro-hydraulic servo loop can be achieved without the use of additional amplifying elements."

(112) AIRCRAFT THERMOCOUPLES.

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Thermo Electric Co., Inc. Bulletin A. Contains illustrations, specifications, and ordering charts covering a line of aircraft thermocouples and thermocouple assemblies. Includes data on three basic types used on reciprocating aircraft engines.

(113) LINEAR-SCALE AMMETERS. Beckman/Helipot Corp. Data Sheet 839, 2 pp. Discusses the design features of a new line of linear scale ac ammeters and the current transformers that improve the meter's accuracy. Standard specifications and dimensions also included.

(114) LIQUID-GAS SEPARATION. Selas Corp. of America. Bulletin S-1052, 10 pp. Describes the Selas Liqui-Jector, a device for the continuous and automatic removal of entrained liquids and solids from air, gas, or steam systems. Cutaway views of each model accompany the description.

(115) HYDRAULIC PILOT VALVE. Atlas Valve Co. Catalog Sheet, 2 pp. Contains photos, diagrams, and descriptive data on two spring-loaded, diaphragm-actuated hydraulic pilot valves. Lists the materials used in each part of the valve, suggests applications, and outlines the most important features.

(116) AIR CONTROL VALVES. Galland-Henning Nopak Div. Catalog No. 105, 16 pp. Covers a new line of pilot-operated, poppet-type air-control valves. Complete dimension, installation, application, and operation data are presented in an easy to use form. Sectional views illustrate internal construction and operation.

(117) COOLING-TOWER CONTROLS. Bailey Meter Co. Bulletin 1050, 4 pp. Describes a newly patented system for automatically controlling make-up water flow, chemical feed, and blowdown rate of cooling towers. A one-page schematic diagram shows the piping arrangement and control system for a typical cooling-tower operation.

(118) FLOATED RATE GYROS. Norden-Ketay Corp. Bulletin No. 419, 4 pp. Deals with a line of floated rate gyros for airborne and control telemetering systems. Principle design features are pointed out on a large cutaway view. General, pickoff, and motor characteristics are listed, along with the environmental operating conditions.

(119) ANALYSIS INSTRUMENTS. Perkin-Elmer Corp. Catalog, 16 pp. Well-illustrated, this small booklet describes the company's line of infrared and ultraviolet spectrophotometers, monochromators, flame photometers, vapor fractometers, briefly describes P-E's process control instruments.

(120) TRUE-LEVEL RECORDER. Bailey Meter Co. Product Specifications M31-2, 4 pp. Deals with a new all-mechanical, compensating level recorder for recording (or indicating) true boiler drum water level in inches. Sketches show the measuring element, temperature equalization column, and helix and cam arrangement that compensates for vessel pressure variations.

(121) WATERPROOF SOLENOID COIL. Hays Mfg. Co. Folder No. 210-3, 2 pp. Describes a new line of waterproof solenoid coils, called "Kast-Coils", that are said to last forever. Folder also contains two tables, one covering coil and valve combinations, and the other coils for existing valves only.

(122) RADIATION PROTECTION. Nuclear Science & Engineering Corp. Bulletin No. 407, 4 pp. Outlines this company's services for health and safety precautions against hazards of radioactivity. These include research and development, technical support, consulting, industrial surveys, etc.

(123) MAGNETIZERS. Indiana Steel Products Co. Bulletin No. 17, 2 pp. Contains data and charts on two new magnetizers. One is an electromagnetic type and the other a permanent magnet type. Pictures of both types are given as well as information on the application and operation of these units.

(124) INDUSTRIAL pH ELECTRODES. Leeds & Northrup Co. Data Sheet N-S5(2), 4 pp. Presents engineering features and ordering instructions for a variety of industrial pH electrodes and their housings. Dip-type immersion heads, continuous flow assemblies, and the new L&N stainless-steel pipeline mountings are also covered.

(125) HYDRAULIC POWER UNITS. J. N. Fauver Co., Inc. Catalog H-257, 8 pp. Contains photographs and blueprints of several hydraulic power units and test stands. These include custom power packages as well as standard units.

(126) BUILDING TEMPERATURE CONTROL. Automatic Devices Co., Inc. Bulletin No. P-257, 4 pp. Covers a number of regulators and time switches for use in automatic-temperature-control systems. A simplified chart contains recommendations for the type of controls to be used under various conditions.

(127) WIRE-WOUND RESISTORS. Kelvin Electric Co. Bulletin CB-2, 2 pp. Describes a new line of precision wire-wound resistors featuring tension-free windings. Provides complete specifications, dimensioned drawings, and descriptions.

(128) AIRCRAFT SYSTEMS. Hamilton Standard Div. of United Aircraft Corp. Booklet, 20 pp. Entitled "Profiles in Progress", this booklet outlines some of the highly-specialized aircraft equipment in use today. It discusses, in layman's language, aircraft-air-conditioning systems, turbine-engine starters, fuel controls, hydraulic pumps, pneumatic valves, and electronic temperature controls.

(129) PNEUMATIC-CONTROL STA-

TIONS. Copes-Vulcan Div. of Blaw-Knox Co. Bulletin No. 1031, 8 pp. Covers a complete new line of auto-manual pneumatic-control stations of the nonseal type. Units are suitable for use as components in combustion control, feedwater regulation, and pressure-reduction systems. Both standard size and miniature devices are described.

(130) THERMOSTATIC CONTROLS. The Franklin Dales Co. Bulletin, 8 pp. Shows the design, construction, and operation of tubular type "Temp-Guard" thermostats that make or break an electrical circuit by responding to changes in either temperature or electrical load. Dimensions and electrical characteristics are tabulated.

(131) LABORATORY GLASSWARE. Fischer & Porter Co. Catalog 80C100, 16 pp. Gives specifications and prices on a complete line of laboratory glassware, including precision-bore burettes, aspirator bottles, gas-collecting tubes, Karl Fischer apparatus, nitrometers, funnels, manifolds, and stopcocks.

(132) TIMING MOTORS. The Lux Clock Mfg. Co., Inc. Form No. 150, 2 pp. Contains descriptive information on a new line of synchronous timing motors. Overall dimensions of the case are given along with dimensioned drawings of the standard brass pinions and ratchets. Includes an enlarged view of the new motor bearing.

(133) LABORATORY INSTRUMENTS. Nurnberg Thermometer Co. Catalog 57. Lists this firm's complete line of thermometers and hydrometers for laboratory and industrial applications. Well-illustrated, the catalog contains a listing of all current ASTM thermometers, hydrometers, and allied testing instruments.

(134) STEAM-PRESSURE VALVE. A. W. Cash Co. Bulletin No. 981. Includes photos and cross-sectional diagrams of this company's Type 44 pilot-operated, pressure-reducing-and-regulating valve. Also contains specifications, pressure and temperature ratings, a capacity chart, installation instructions, and suggested applications.

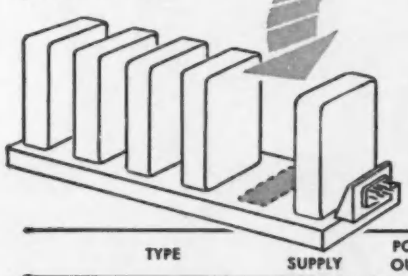
(135) COPPER-CLAD LAMINATE. Formica Corp. Brochure No. 755, 4 pp. Describes the physical and electrical properties of "Cirprint", a new copper-clad laminated plastic especially designed for large-volume manufacturers of electrical and electronic products. Table on last page compares properties of the new material with those of earlier grades.

(136) VENTURI TUBES. Burgess-Manning Co. Bulletin 400. Offers cross-section illustrations of two types of venturis for metering water, sewage, sludge, air, and other fluids. Describes design features of each, suggests its best applications.

(137) CONTROL GLOSSARY. Manning, Maxwell & Moore, Inc. Bulletin, 12 pp. An up-to-date glossary of automatic control terms, now available for the asking, contains all the ASME approved terms plus a few that have recently crept into the control engineer's language. It definitely should prove interesting to newcomers and should also encourage the use of accepted terms in everyday conversation and correspondence.

Lightweight! SERVO Magnetic Amplifiers

The servo amplifiers illustrated are typical standard types. Other models, including higher power types, are available for systems engineering. The complete MA line offers the designer a choice of compact, low cost types, amplifiers featuring fast response at high gain and all-magnetic models providing highest performance.



In addition to standard types, custom designs can be produced for special applications, or complete servo and automatic control systems can be engineered to your requirements.

TYPE	SUPPLY	POWER OUTPUT	SENSITIVITY	RESPONSE TIME—SEC.
LIGHTWEIGHT SUB-MINIATURE MAGNETIC AMPLIFIER	115 volts 400 cps.	½, 3, 5, 10 watts	.02 volts	.003
MAGNETIC PRE-AMP + SATURABLE TRANSFORMERS	115 volts 400 cps.	3, 5, 6, 10, 18 watts	1 volt AC	.03
MAGNETIC PRE-AMP + HIGH GAIN MAGNETIC AMPLIFIER	115 volts 400 cps.	5, 10, 15, 20 watts	0.1 volt AC	.008 to .1
TRANSI-MAG*: TRANSISTOR + HIGH GAIN MAGNETIC AMPLIFIER	115 volts 400 or 60 cps.	2, 5, 10, 15, 20 watts	.08 volt AC into 10,000 ohms	.01

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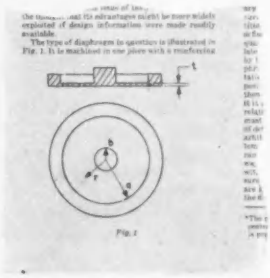
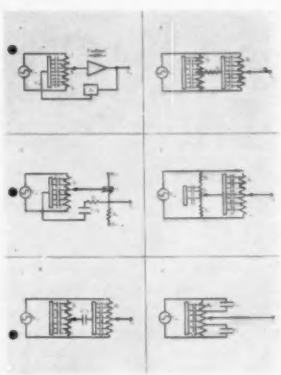
APPLICATION LITERATURE

(138) REINFORCED FLAT DIAPHRAGMS. Statham Laboratories, Inc. Instrument Notes No. 31, 4 pp. Really a four-page technical article, this paper deals with the theory of flat-annular diaphragms, and should be of interest to anyone concerned with the design of highly accurate pressure-measuring devices. As author



C. K. Stedman points out, a good deal of information has been published on flat-plate diaphragms having no central reinforcement. Less familiar but far more versatile is the diaphragm with a central reinforcing boss and a stiff annular ring around the outside edge. Figure 1 of the article (above) shows a typical cross-sectional view of such a unit.

(139) CORRECTING PHASE SHIFT IN COPPER-MANDREL POTS. Beckman/Helipot Corp. Technical paper No. 552, 32 pp. "Measurement and Correction of Phase Shift in Copper-Mandrel Precision Potentiometers" is the title of this 32-page paper. In it, authors S. Schneider, F. Hiraoka, and C. Gauldin discuss a practical approach to the problems of predict-



ing, measuring, and compensating for quadrature voltage and phase-shift in copper-mandrel pots used in ac circuits. Separate sections cover test circuits for quadrature and in-phase voltage measurements, measurement of mandrel-to-resistance-wire capacitance, and comparison of results with theoretical equations. Page 17, shown here, illustrates six different types of phase-compensation circuits; it is followed by a chart containing values for

Locates Measures Corrects

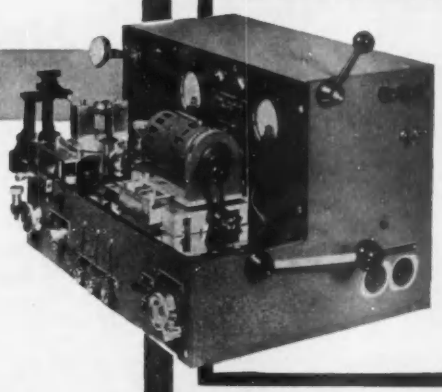
Detailed information is in Instrument Data Sheet 211, available upon request to Technical Literature Section.

DYNAMIC UNBALANCE

of miniature high speed gyro rotors

without removing the rotor from the mount

decker **DYNAMIC BALANCER**



Even miniature missile type gyro rotors can be balanced in 6 to 10 minutes with the DECKER DYNAMIC BALANCER. And ultimate balance is generally limited only by the quality of the rotor bearings.

Designed specifically for high speed rotors requiring maximum possible precision of balance, the Model 211 Dynamic Balancer is capable of handling any rotor which may be electrically driven at 10,500 rpm or higher.

The Balancer offers, on a single portable chassis, everything needed for precision dynamic balancing. Included are the necessary equipment for rotor mounting, measurement, and location of unbalance, plus a precise metered automatic drill for unbalance correction.

- **Maintains laboratory type precision balance on a production basis**
- **Does not require a skilled technician**
- **Automatic marking of point of unbalance**
- **Drilling performed without removing rotor.**
- **Precise indication of degree of unbalance**
- **Automatic speed control**
- **Rapid run up to proper speed**
- **Completely self contained and portable (11" x 15" x 21")**
- **Rapid work change over**

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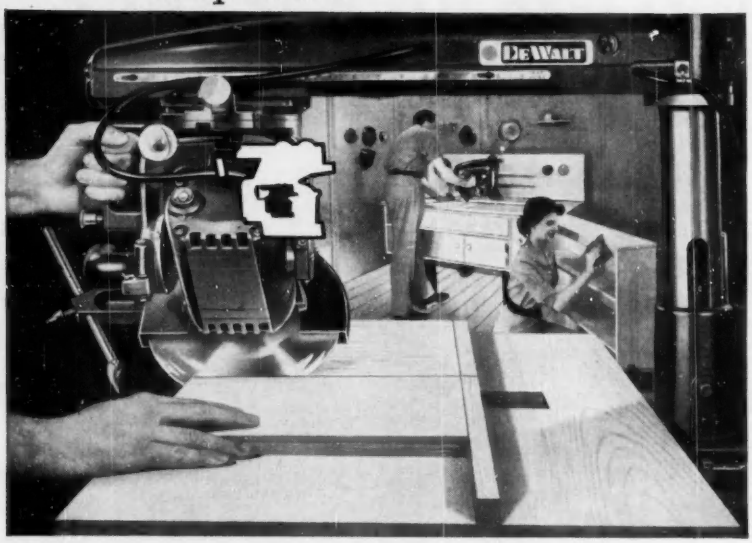
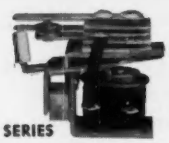
Potter & Brumfield *engineering is in this picture*

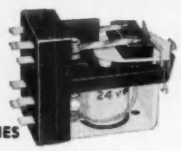


Which P&B relay would you specify for this

HIGH STARTING TORQUE MOTOR?


MP SERIES

MS SERIES



AB SERIES

Radial Saws by DeWalt, Inc. are used in thousands of home work shops, in lumber yards, carpenter shops and industry. The electric motors that operate these saws are a heavy duty single phase, AC, modern capacitor, voltage relay type. They have a ***high starting torque*** in order to quickly achieve operating speed, even when heavy line loads give lower voltage than normal. To avoid arcing and burning during initial current surge, DeWalt needed a positive, fast acting relay that would remain in contact until operating speed was reached.

Their choice? P&B MP series relays! These sturdy relays not only save arcing and burning during initial current surge, but are compact, rugged and dependable. Their versatility permits use with any capacitor type motor up to 2 horsepower. They can be furnished with an alnico magnet if whole snap action is needed.

This ready solution to DeWalt's relay problem is an example of how P&B relay engineering is daily adapting existing relay types to specific needs. P&B's unique 25 years of relay engineering experience provides an immense reservoir of skill, information and technical ability that can help solve your relay problems faster and more efficiently.

ENGINEERING DATA

SERIES: MP. Small general purpose power relay.
CONTACTS: ⅜" fine silver rated 25 amp., 115 V. AC non-inductive load, or 2 HP, 115 V. AC.
CONTACT ARRANGEMENTS: SPST NO, SPST NC, SPDT.
VOLTAGE RANGE: DC: Up to 220 V. AC: Up to 230 V.
COIL RESISTANCE: 15,000 ohm maximum.
TEMPERATURE RANGE: DC: −55° C. to +85°C. AC:−55°C. to +55°C.
TERMINALS: Standard pierced solder lug holes will take No. 10 hook-up wire.
ENCLOSURES: Dust cover, 2-59/64" L x 2¼" W. x 2-3/32" H. Hermetically sealed cover dimensions same as above.
DIMENSIONS: Maximum 2¼" L x 1¼" W. x 1⅞" H.
This relay will normally deliver a minimum of 300,000 operations before wear will warrant readjustment.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC, ELECTRICAL, AND REFRIGERATOR DISTRIBUTORS

See our catalog in Sweet's Product Design File

Potter & Brumfield, inc.

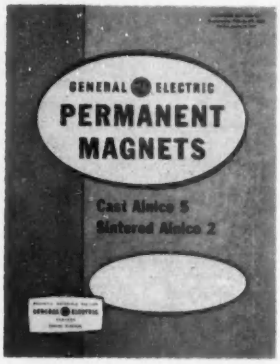
PRINCETON, INDIANA *Subsidiary of* **AMERICAN MACHINE & FOUNDRY COMPANY**

Manufacturing Divisions also in Franklin, Ky. and Laconia, N. H.

APPLICATION LITERATURE

the various circuit parameters and quadrature voltages.

(140) CAST AND SINTERED MAGNETS. General Electric Co. Catalog PM-121, 12 pp. This bulletin, superseding Catalog PM-100, contains a good deal of information useful to the component designer. It covers both cast (Alnico 5) and



sintered (Alnico 2) products. Photographs of every available shape are accompanied by drawings and tables. Each table gives the catalog number, dimensions, and weight of each model.

(141) "NOTES ON LINEAR DIFFERENTIAL TRANSFORMERS". Schaevitz Engineering. Bulletin AA-1a, 20 pp. Questions on the techniques involved in the use of linear variable-differential transformers are answered in detail in this illustrated brochure. A summary of the mechanical and electrical features of this

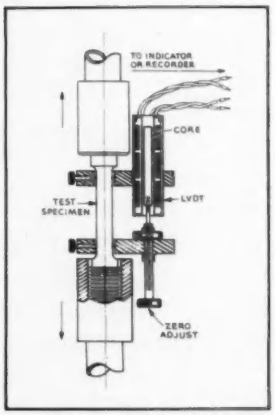
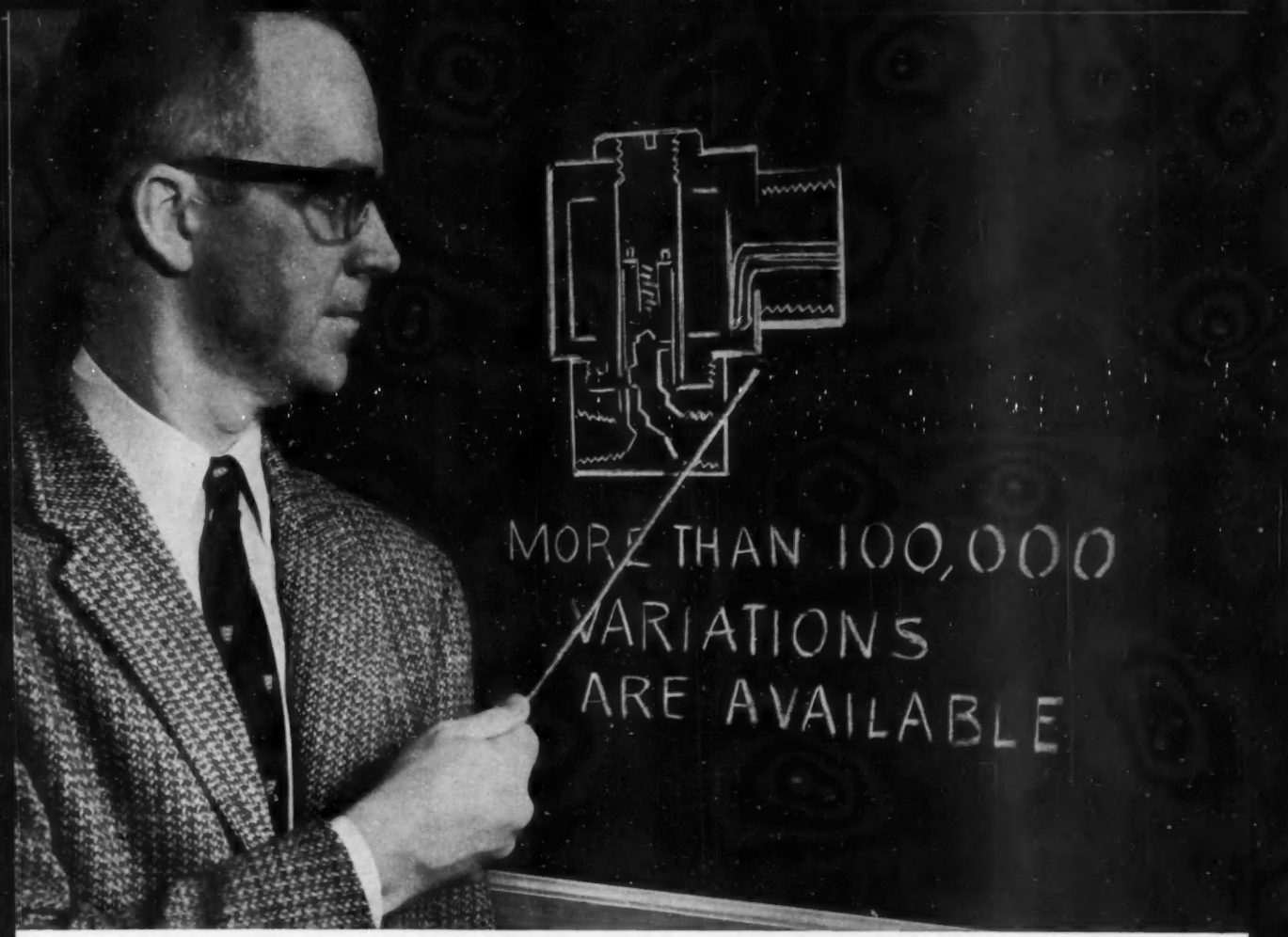


Figure 30. Use of LVDT in extensometer.

basic transducer is followed by sections on fundamentals of LVDT applications, characteristics of the Schaevitz LVDT, environmental factors, and installation and operation. Graphs, charts, circuit diagrams, and line drawings are used throughout to illustrate construction, characteristics, and applications of these units. Figure 30, above, is typical of the drawings.



You can get the *custom designs* you want from a basic Skinner Solenoid Valve

In the small-size solenoid valve field, Skinner offers a wider variety of variations and optional features than any other manufacturer. Take, for example, the standard V5 model shown above in cutaway form. Its design is so flexible that the valve can be supplied for applications which would otherwise call for "specials." So, if you have a solenoid valve problem, we urge you to talk to a Skinner representative. Tell him your requirements in regard to port sizes and locations, voltages, pressures, temperature conditions, flow adjustments and mountings. Let him show you how easily he can select the valve you need.

When you specify Skinner, you get custom design plus outstanding service performance. Continuous testing in our labs and actual results in the field prove that Skinner valves have exceptional leakproof life. For complete information on Skinner's line of 2-, 3- and 4-way valves, write us or contact a Skinner representative. Write Dept. 345

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Lower production costs, improved quality control and inspection, smoother traffic flow, less labor waste, better safety conditions are just a few of the benefits offered by B-T industrial TV products.

The B-T Observer TV camera offers effective closed circuit television at low cost. Now, with the exclusive B-T AUTOMATIC LIGHT COMPENSATOR, the camera operation is rendered completely automatic further broadening its scope in industrial applications.

The Automatic Light Compensator automatically handles light variations as great as 150 times, i.e., 5 to 750 foot candles or vice versa. Despite wide and frequent changes in light intensity at the subject, it is now possible to observe a constantly clear, well-defined image on the viewing screen. This eliminates the need for manual or remote adjustment of lens iris or camera controls.

B-T industrial TV extends the range of your vision beyond your office, or lab to remote, hazardous or inaccessible locations. Here are some industrial TV systems, now in operation, using the B-T Observer:

- **A textile manufacturer links the design and embroidery machine department located on different floors for quality and process control.**
- **A Pennsylvania steel mill watches furnace and rolling operations. Exclusive B-T Automatic Light Compensator overcame problem of sharp changes in light intensity at the subject.**
- **A midwestern cement manufacturer checks composition and flow of slurry into a kiln, preventing costly damage due to congestion. Saves $36.00 a day in manpower and material.**
- **A lumber company prevents log jam damage, also identifies wood types (proof of the clarity of the TV picture) by observing the bark structure.**
- **A Los Angeles utility has a multi-camera setup for flame control.**

A complete industrial TV system – B-T Observer TV camera, with f1.9 lens, B-T Automatic Light Compensator, one monitor (receiver), and cable – can be installed, ready to operate for under $2,500.

There's a qualified B-T distributor in your area with complete engineering facilities to serve your specific needs. For further information write to Dept. CE-5.

BLONDER-TONGUE LABORATORIES, INC.

9-25 Alling Street Newark 2, N.J.

The largest manufacturer of TV Signal Amplifiers, UHF Converters and Master TV Systems

WHAT'S NEW

(Continued from page 52)

net income $3,492,000 (under a method of inventory evaluation which reduces the reported book profits during period of rising costs, but increases the cash generation by a reduction of Federal income taxes); capital down 6.6 percent or $48,903,000.

Beckman Computing Center Operating in Los Angeles

Computation centers in the Los Angeles area are increasing. Latest big control firm to set one up there is Beckman Instruments, Inc., whose Berkeley Div. is operating the new center under George A. Bekey, manager and senior engineer. Problems relating to aircraft, missiles, jets, and industrial processes will be submitted by industrial, scientific, and educational institutions throughout the Pacific Southwest. The Berkeley Div. is also at work on a new Boeing Airplane Co. contract, which calls for an electronic computer able to solve up to six jet aircraft engineering problems simultaneously. Delivery of the six-analog-computer system is scheduled for June.

Caltech Lab Gets Biggest Army Award: $21 Million

The Caltech Jet Propulsion Laboratory has received its biggest slice of Army funds since the government sponsored it as a rocket research unit. The money, amounting to $21 million for the calendar year 1957, brings the value of Army contracts for guided missile work to nearly $115 million. The laboratory, which was the birthplace of the Corporal missile, the first successful jet-assisted takeoff units, and the first two-stage rocket, the Bumper Wac, is also in line for a $6-million contract, coming soon.

Texas Instruments Enters Xerographic Oscillography

Texas Instruments, Inc., has been issued a license to manufacture and sell oscillographic equipment using the xerographic reproduction process developed by The Haloid Co. of Rochester, N. Y., which is proving successful in, among other things, increasing computer output speeds (CtE, Feb., p. 40). Patents on the process are held by Haloid, and by Century Electronics & Instruments, Inc., which pioneered its use in oscillography.

The Houston company, which has

CAKE MIX IN A "JIFFY" WITH

CYPAK

Controlling automatic storage conveyors at Chelsea's modern food plant

Chelsea Milling Company, maker of well-known "Jiffy" brand premixed foods, uses flexible CYPAK* static control to reduce material handling costs in their plant at Chelsea, Michigan.

CYPAK begins at the mixing and packaging machines, memorizing the sequence of cartons going to the warehouse. Cartons are identified automatically, and then CYPAK directs storage according to the preselected pattern.

Subsequent delivery of cartons from storage to dock is also completely predetermined, making the warehousing operation totally automatic. An additional benefit realized by Chelsea with this system has been great reduction in carton breakage.

For complete information on CYPAK, call your Westinghouse representative, or write Westinghouse Electric Corporation, P.O. Box 868, 3 Gateway Center, Pittsburgh 30, Pennsylvania.

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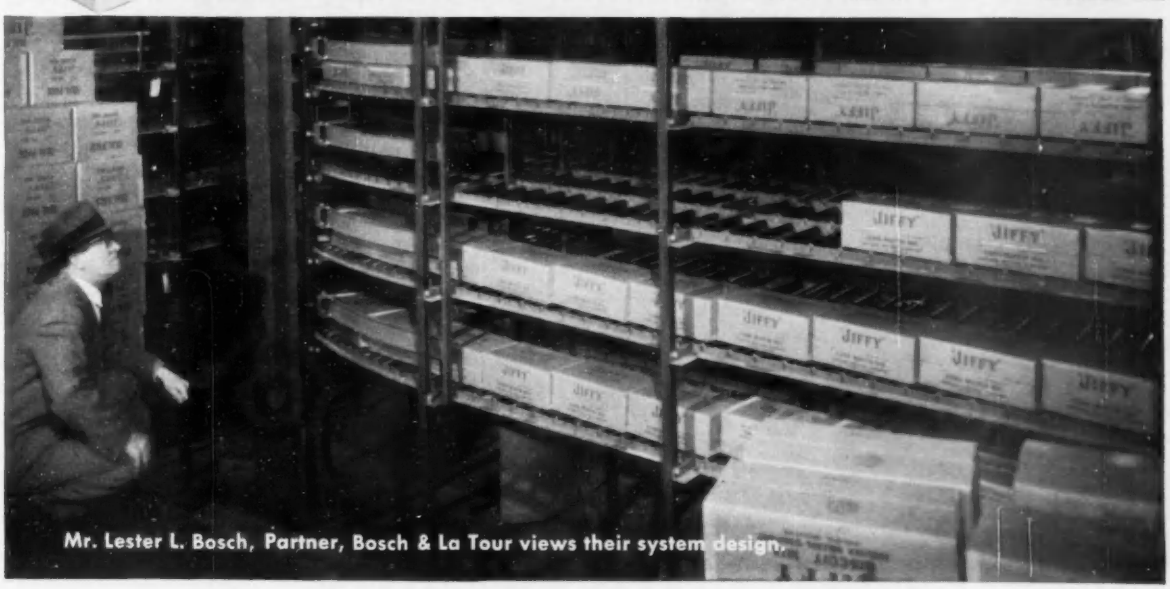

Mr. Lester L. Bosch, Partner, Bosch & La Tour views their system design.

FOR DATA PROCESSING COMPONENTS AND SYSTEMS

SPECIFY POTTER

Potter instruments and systems are unexcelled in reliability, accuracy and flexibility. The equipment shown is typical of many more available as individual components or in integrated systems to meet specific requirements.

Write for brochure describing these and other Potter units, including special products. For detailed technical specifications on any of the Potter Products listed above, contact your Potter Representative or the factory.

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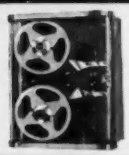
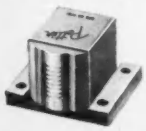


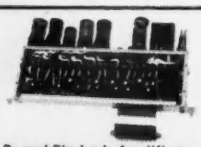
Digital Magnetic Tape Handlers

Perforated Tape Readers

"Quick Look" Recorders



Record-Playback Head Assemblies



Record-Playback Amplifiers

PRESET INTERVAL GENERATORS

Preset Interval and Delay Generators

HIGH SPEED ACCESS REGISTERS

Ten-Bit Parallel Output (Serial Input) Using Magnistors

Ten-Bit Serial Output (Parallel Input) Using Magnistors

Six-Bit Digital Comparator Using Magnistors

POTTER INSTRUMENT COMPANY, INC.
115 Cutter Mill Road Great Neck, L. I., N. Y.

WHAT'S NEW

gained a handsome reputation in the semiconductor field, has established a new subsidiary near London, England, to be known as Texas Instruments, Ltd. It will manufacture and sell a full range of silicon and germanium semiconductor products, including transistors, diodes, and rectifiers, in the United Kingdom. Managing director of the new enterprise is Dudley Saward, prominent in the British electronics field.

Air Motor Maker Joins Richardson at Geneva

Richardson Scales S.A., the foreign concern formed in 1952 by Richardson Scale Co. of Clifton, N. J., to manufacture and sell materials-handling equipment in Europe, has been joined in Geneva, Switzerland, by The Bellows Co. of Akron, Ohio, maker of air motors and other controlled-air-power devices. The result is a new company, Richardson-Bellows S.A. It marks, said Presidents Ingram Richardson and Herbert B. Link, "a significant forward step in the development of an international industrial picture. It represents a trend that will serve to combine the best aspects of American technology and industry with the continually expanding European market."

Managing director of the new company is Louis Perrin, a Swiss engineer.

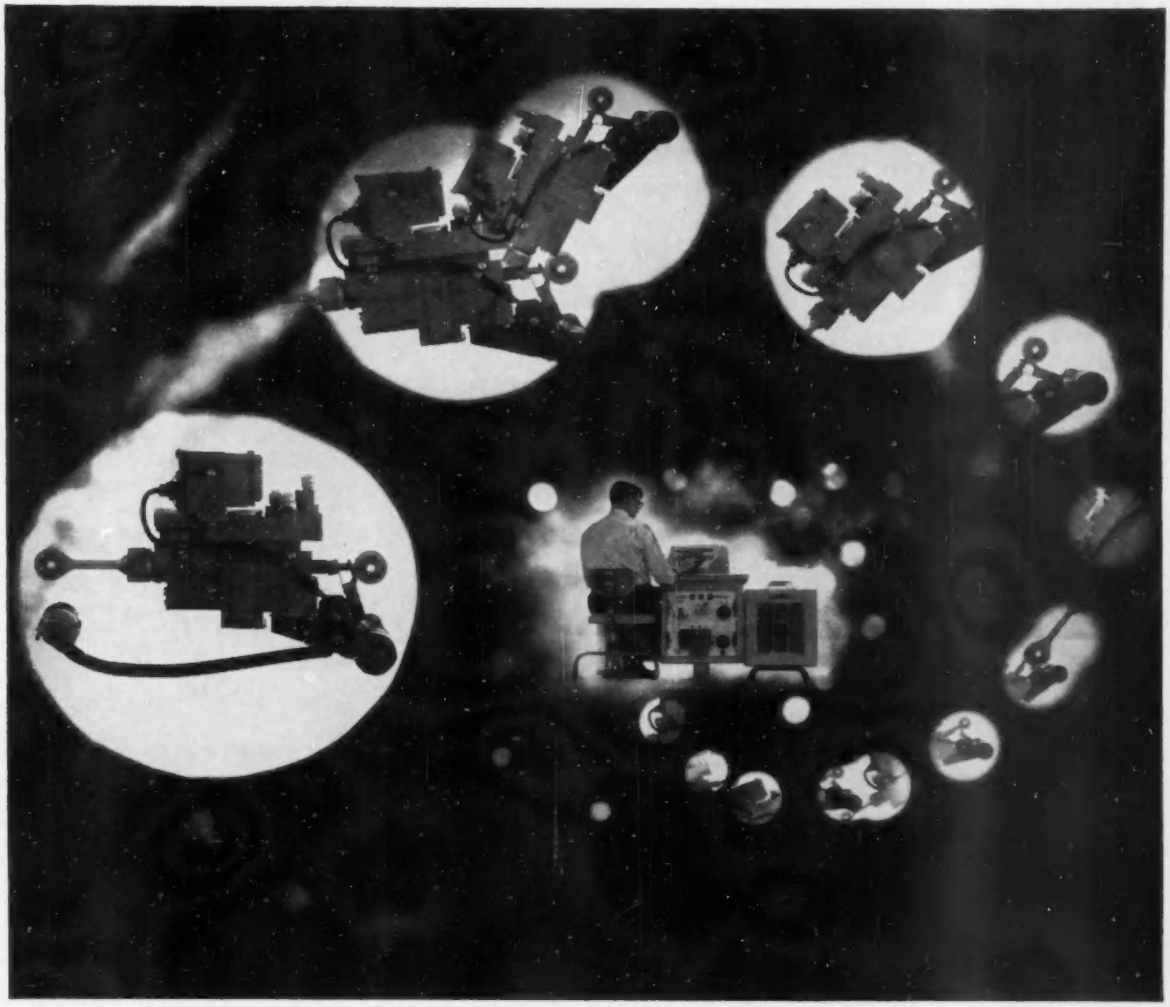
Other Developments

► **Logistics Research,** manufacturer of Alwac electronic data processing systems, has changed its name to **Alwac Corp.,** a title which "will provide better identification with the company's products and services, which all bear the Alwac name". Concurrent with the change, the company moves into two new buildings in Hawthorne, Calif., where a new computing and training center shares 70,000 sq ft with larger manufacturing facilities.

► Another company that has changed its name is **Air Associates, Inc.,** which henceforth will be known as **Electronic Communications, Inc.** A new emphasis on electronic research and a change of location (from Teterboro, N. J., to St. Petersburg, Fla.,) accompany the change. The name Air Associates will be retained for an ECI aviation supplies division.

► New divisions and departments have been formed in recent weeks by:

Atlantic Research Corp., whose new



Man's electro-mechanical partners are bringing his ideas to life faster...better...at less cost

Today one of industry's most formidable tasks is to streamline and shorten the time-consuming process that transforms ideas into exciting new products.

Never in man's history has this embryonic period needed to be shortened more than now—when technological superiority could very well be the world's best hope for peace.

And nowhere is this challenge being met more energetically than in the development and production of automatic control systems at AUTONETICS. A whole new breed of electronic and electro-mechanical tools and techniques is being evolved to shorten lead time. A notable example is *Numill*, AUTONETICS' new tape-directed numerical machine-tool control system. *Numill* is entirely digital, and can convert a numerical engineering description into a prototype configuration—quickly, economically and with consistent accuracy.

Standardized "postage-stamp" circuits allow engineers to mockup even highly advanced designs almost as simply as they would plug in an electric shaver. And AUTONETICS' data processing equipment can simulate a wide range of operational missions, as well as solve the most involved mathematical problems in minutes instead of days.

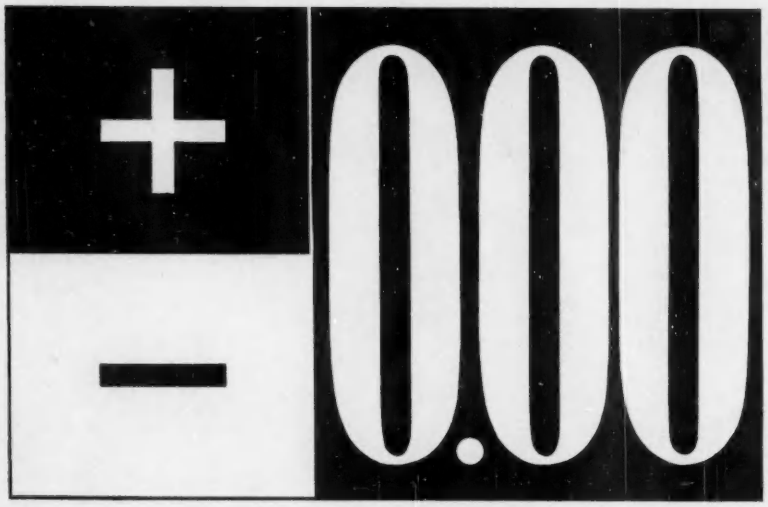
AUTONETICS' ability to save time and money between concept and product delivery is reflected in every area of its electro-mechanical technology: flight controls, inertial navigation, armament controls, computers, and other complete systems for the military and industry.

For detailed information, or for employment in this dynamic field—write: AUTONETICS, Dept. CON-73, 9150 E. Imperial Hwy., Downey, California.

Autonetics

A DIVISION OF NORTH AMERICAN AVIATION, INC.

AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE



• • • tolerance

Without quibble or qualification, a Meriam Manometer delivers perfect reproducible accuracy. This accuracy is absolute . . . no plus, no minus. Right on the button.
The same differential will always produce the same column height. Not close to the same height, but exactly the same height.
Other instruments struggle to come close. In a manometer, perfect reproducibility is inherent. It is routine . . . effortless.
How closely do you wish to "read-out" this perfect reproducibility? There are over one thousand different Meriam Manometer forms to answer this question. Sensitivity is selective, depending on the indicating fluid used. For example, one form of Meriam Inclined Manometer, using water, will provide graduations a full tenth of a linear inch apart, equal to 0.0005 psig.
Most important, Meriam has placed this perfect reproducible accuracy at the disposal of the plant operator as well as the lab technician. Rugged models serve along process lines outdoors as well as on central control panels.

NEW

. . . complete and informative guide to manometer theory and practice as well as manometer models for plant, field and laboratory use. Just ask for Bulletin G-14. The Meriam Instrument Company, 10920 Madison Avenue, Cleveland 2, Ohio.

MERIAM MANOMETERS
...always accurate

WHAT'S NEW

Western Div., under director Joseph Philipson, is the first branch unit established to serve particular geographic areas. Headquarters are at Pasadena, Calif. Other key men in the division: Howard H. Niederman, formerly with Aerojet-General Corp., and J. Russell McGibbeny, formerly with U.S. Flare Corp. & Associates.

Topp Industries, Inc., whose new HRB-San Diego Laboratories Div. has opened an R&D facility in San Diego under Benjamin R. Gardner Jr., senior engineer with Haller, Raymond & Brown, Inc., a Topp subsidiary. Gardner, formerly president of Techniques, Inc., has also been with Consolidated Vultee Aircraft Corp. and the U.S. Army Air Corps in radio countermeasures work.

North American Mfg. Co., whose Hydraulic Controls Div., under Clark E. Hague, director of engineering, will concentrate on a high-gain hydraulic amplifier for pressure regulation, flow control, edge guide, process control, and other applications requiring signal amplification. Hague most recently was president of Hague Regulator Co. Before that he was with Askania Regulator Co.

Vickers, Inc., which continues a program of decentralization with these four new divisions: Aero Hydraulics, under General Manager Ben W. Badenoch; Machinery Hydraulics, under General Manager M. A. Hayden; Mobile Hydraulics, under General Manager Ray Conner; and International, under R. E. Esch.

Induction Motors Corp., which has set up a West Coast Rotating Components Div. under PSP Engineering Co. of South Gate, Calif., a new subsidiary. Special emphasis will be put on military-type synchros, resolvers, and rotating components.

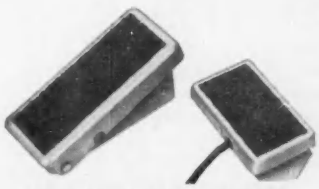
Bendix Computer Div., whose new Digital Computation Laboratory at Los Angeles, under Tak Yamashita, will do analysis work, programming, and machine computation for outside customers. On hand are two Bendix G-15 general-purpose computers, a DA-1 digital differential analyzer accessory, magnetic-tape units, punched-card input-output equipment, and a paper-tape preparation unit.

Burroughs Corp., whose International Div., under Vice-President Ray W. Macdonald, will have charge of all marketing operations outside the U.S. and Canada, as well as certain manufacturing and engineering facilities in England, Scotland, France, and Brazil. Working with Macdonald will be General Mfg. Manager Robert A.

HETHERINGTON

SWITCHES • INDICATOR LIGHTS • SPECIAL ASSEMBLIES

ENGINEERING NEWS #4

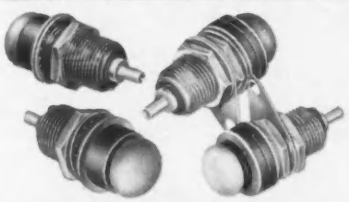


FOOT SWITCHES SIMPLIFY COMPLEX SWITCHING PROBLEMS

For many control operations, the foot is often quicker than the hand and a whole lot more convenient—especially where many switches must be attended or where the operator's hands must be freed for other more exacting chores.

Foot switches can often handle heavy-duty multiple-pole, 2 or 3-position switching more reliably, more conveniently, and with decided savings in panel space compared to hand-operated switches or relay circuits.

The two Hetherington Foot-operated Switches illustrated can be supplied in a wide number of single and double-pole circuit arrangements with ratings up to 15 amps, 115 volts ac. Sturdy aluminum frames have a non-skid abrasive compound on treadles.



SPACE-SAVER LIGHTS

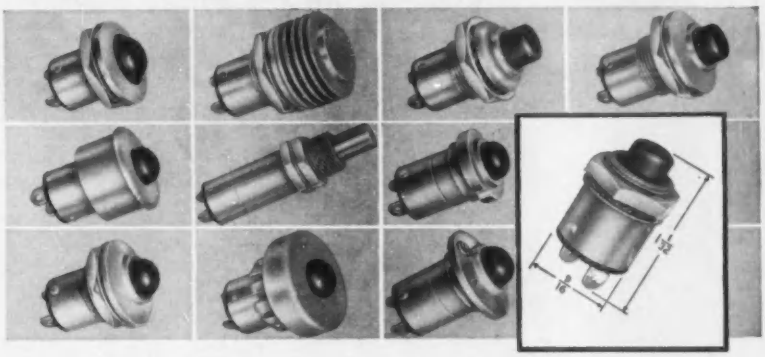
for Standard or Edge-Lit Panels

Only 1¼ inches from terminal to lens, these tiny indicator lights give bright and moderately wide-angle visibility in minimum front-panel area. Colored plastic lenses unscrew from the front for quick replacement of AN3140 lamps; 6, 14, 18, or 28 volts.

One-piece terminal and contact assemblies are solidly molded as an integral part of the assembly. Lamp circuits cannot be broken by pulling on the terminal.

Full details on Hetherington Series L1000 (for regular panels), or Series L2000 (for edge-lit aircraft panels) are in Bulletin L-1.

THE SWITCH WITH THE 1,800 PIECE WARDROBE



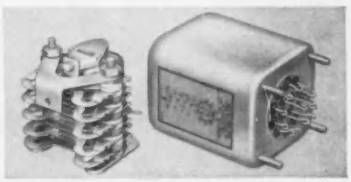
Take any Hetherington "JR"-Series Switch, screw on any of 14 anodized aluminum adapters such as those above, and you have a totally different unit . . . in style as well as in mounting characteristics.

Most adapters can be furnished with any of 2 or 3 different auxiliary push buttons to meet individual requirements. In addition, any of 7 or 8 colors can be added to either or both the adapter or button —making a total of more than 1,800 possible combinations for *each* of the six basic switch circuits.

Adapters range from standard flange-mounting types to force-fit, blind-hole, and molded stick-grip types. Many can be engraved in ⅛-inch letters to indicate switch function.

"JR"-Series Switches use the positive Hetherington snap-action mechanism rated for 17 amps at 28 volts dc, or UL Inspected for 15 amps at 115 volts ac.

Complete ratings, specifications and dimensions of all switches and adapters are shown in Bulletin S-5.



JET-AGE RELAYS

Meet Tough Shock and Vibration Specs

Designed originally to withstand the extreme shock, vibration, and high temperatures of high altitude aircraft, missiles, and rockets, these Hetherington G-Series Relays have proved remarkably successful and economical for many less exacting earth-bound applications as well. Typical aircraft types with up to 6 single-throw or 4P-DT contacts, withstand 20G vibration at over 500 cycles. Temperature barriers have been raised to 600°F in many specific types. Single and multiple-unit assemblies are available in a variety of open, dust-proof, and hermetically-sealed types with contact ratings up to 10 amps.

Industrial models for less critical applications are available at correspondingly lower prices.

Details are in Bulletin R-1.

WHEN YOU NEED SWITCHES IN A *HURRY*

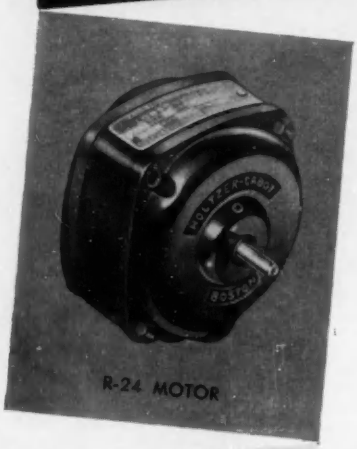
Small quantities of many Hetherington products are now stocked for same-day delivery on both the East and West Coasts. See your local Hetherington sales engineer for an up-to-date list of stock items.

HETHERINGTON INC. 1200 ELMWOOD AVE., SHARON HILL, PA. • 139 Illinois St., El Segundo, Calif.

. . . for jobs where a better switch is far-sighted economy

HOLTZER -CABOT

Instrument Control Motors



The R-24 4-pole induction motor, with reversible rotation, is adaptable to a wide variety of applications. Typical uses are in servo mechanisms; as a balancing motor in recording instruments, and as a control motor for voltage regulators. When operated 2 phase, it can be controlled electronically; it can also be run single phase as a permanent split capacitor motor.

Specifically engineered to operate effectively with other engineering apparatus. Also available with gear-train. Send coupon below for additional information.

HOLTZER-CABOT MOTOR DIVISION
NATIONAL PNEUMATIC CO., INC.
125 Amory Street, Boston 19, Mass.

GENTLEMEN: ☐ Please send me data sheets on the Holtzer-Cabot R-24 Motors.

☐ Please have representative call on..... (date)

Name.....

Company.....

Street.....

City.....Zone.....State.....

Atkins, now in charge of overseas manufacturing.

Stromberg-Carlson, whose new developmental cathode-ray tube facility in San Diego, under Howard W. Grossbohlin, head of the Tube & Components Engineering Dept., is said to be the first of its type on the West Coast. Much of the work at San Diego will involve refining models of the Charactron shaped-beam tube, one version of which is used in SAGE.

IMPORTANT MOVES BY KEY PEOPLE

Hilberry Named Director of Argonne National Laboratory

Among the 41 people present in the University of Chicago's Stagg Field on Dec. 2, 1942, when the first controlled nuclear chain reaction in history took place, was Norman Hilberry, who was then working in the university's Metallurgical Laboratory as assistant to Arthur H. Compton. Hilberry had come to the project the year before from the physics faculty of New York University, which he had joined in 1925 as a specialist in cosmic rays and applied physics and engineering. In 1946 the Chicago Laboratory was taken under the wing of the Manhattan District, which changed its name to Argonne National Laboratory and turned it over to the AEC. At the same time Hilberry was appointed deputy director under Director Walter Zinn.

Last June Zinn resigned, and the laboratory was left without a director. But the position he vacated was an important one, and Argonne felt obliged to rule out any hasty decision on a successor. Just recently, after nearly a year of deliberation, UC's Chancellor Lawrence A. Kimpton announced that Norman Hilberry was the man for the job.

Hilberry has played key roles in other nuclear projects besides the one at Argonne. Among them: the first pilot plutonium-producing reactor at Oak Ridge, Tenn., the plutonium plant at Hanford, Wash., the UC cosmic ray expedition to Peru and Brazil in 1941, the first studies on the life of the mesotron (with Bruno Rossi and others).

Other Important Moves

▶ After six and a half years in the east, where he served as R&D engineer with Foster Engineering Co. and instrument consultant to Ebasco Services, **Chester S. Beard,** an author-

C. S. Beard

O. C. Bowers

D. E. Brown

W. G. Driscoll

Bruce Seddon

W. M. Pierce Jr.

THE HEART

of this Differential Voltmeter

is an Airpax Chopper

A chopper amplifier extends the range of this null-reading VTVM down to 0 ± 0.01 DC volt. An Airpax Type 175 chopper modulates the input signal at 60 CPS so that it can readily be amplified and then the chopper synchronously rectifies the signal and returns it to the DC portion of the meter.

Here is another example of how a reliable chopper helps provide the stability essential to modern electronic equipment. This particular instrument is one of the precision laboratory meters developed by John Fluke Manufacturing Co., Seattle, Washington.

Type 175 chopper is one of the Airpax family of miniature choppers. For full details just write to

CHARACTERISTICS OF TYPE 175 CHOPPER

Drive

Frequency	60 ± 3 CPS
Voltage	6.3 ± 0.6 RMS volts

Contacts

Dwell Time	167 ± 10 electrical deg.
Balance	within 15 electrical deg.
Phase angle	20 ± 5 electrical deg.
Voltage	up to 100 DC volts
Current	up to 2 MA
Noise	50 microvolts average
Life	2,000 hours

Hermetically sealed for trouble-free operation in any atmosphere, humidity, or altitude.

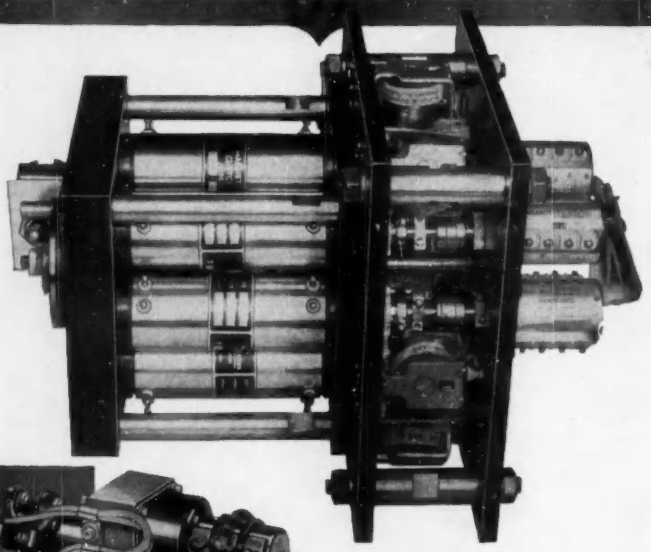
AIRPAX PRODUCTS COMPANY

DESIGNERS ENGINEERS

MIDDLE RIVER • BALTIMORE 20, MD.

BOWMAR

PRECISION ELECTROMECHANICAL ASSEMBLIES



FUEL CONTROL ASSEMBLY

1062 SPEED REDUCER

2216 LONGITUDINAL COUNTER

Illustrated above is a seven-stage servo storage unit designed and built by Bowmar Instrument Corporation in its Fort Wayne engineering and manufacturing plants. It is one of many such ultra-precision assemblies created by Bowmar for use in military and industrial control systems. Here is one more example of Bowmar's skill and experience in the control instrumentation field . . . *one more reason why more firms are using Bowmar's facilities for their most serious projects.*

Manufacturers of

PRECISION ELECTROMECHANICAL ASSEMBLIES, PRECISION SPEED REDUCERS, GEAR HEADS AND MECHANICAL COUNTERS

SEND FOR BROCHURE

Bowmar INSTRUMENT CORP.

2200 PENNSYLVANIA STREET • FORT WAYNE, INDIANA

WHAT'S NEW

ity on instrumentation and controls, returns to the West Coast as head of the Controls, Valves & Actuators Engineering Div. of General Controls Co. Beard, whose headquarters will be at the company's Western Research & Development Center in Glendale, Calif., is back in familiar territory: before leaving for the east, he had been with some half-dozen California companies, including Permanente Metals, Inc., Southern California Gas Co., and Bechtel Corp. An active man in the ISA, he has been national vice-president of the Northeast District and president of the New York and the Northern California Sections. He is also a writer on his field: one book, on control valves and actuators, will be published shortly; another, on regulators, is in preparation.

▶ **Orrin C. Bowers,** the new chief engineer of BJ Electronics, comes to the Borg-Warner facility from The Ramo-Wooldridge Corp., where he had been projects manager of the Electronic Instrumentation Div. Before that he was a divisional chief engineer of Packard-Bell Co.

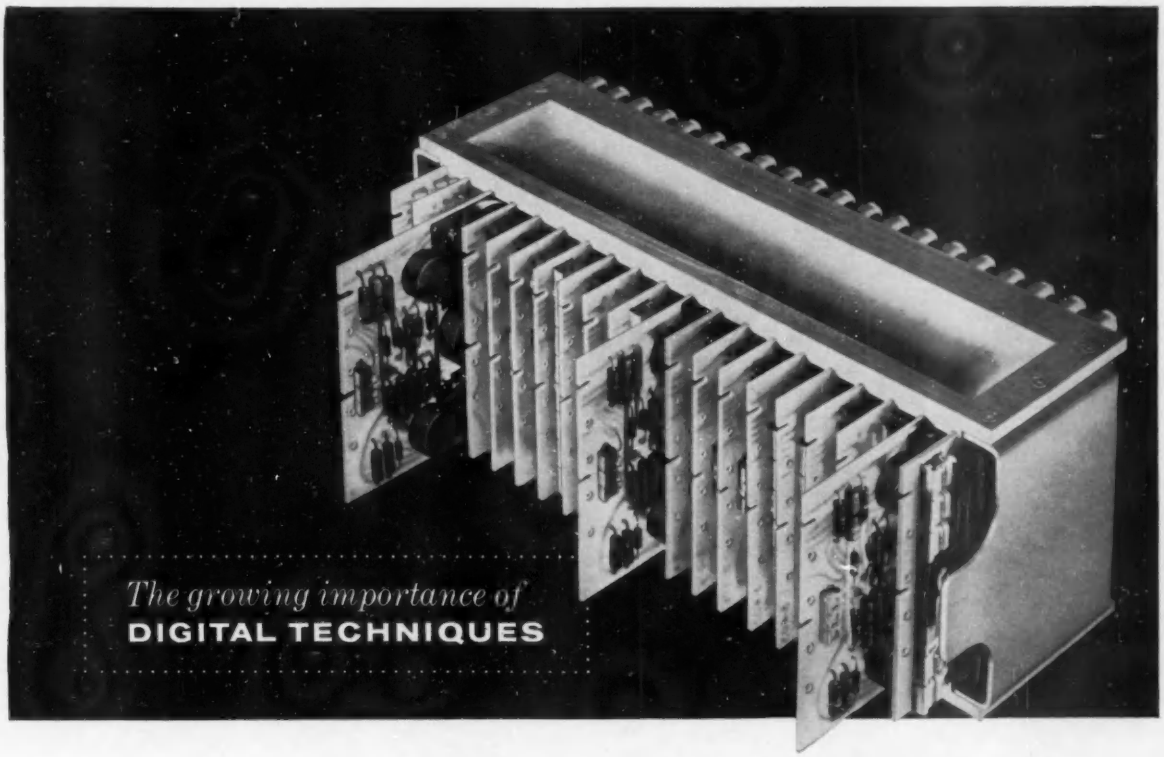
▶ **Donald E. Brown,** who takes over as chief engineer of the Glendale Div. of Consolidated Electrodynamics Corp., was with the Johns Hopkins Applied Physics Laboratory and Vitro Corp. before joining CEC a year ago as a specialist in advanced electronic techniques. His division is the former R. A. Castell & Co.

▶ As vice-president for research at Baird-Atomic, Inc. (formerly Baird Associates-Atomic Instrument Co.), **Walter G. Driscoll** will continue to handle the duties associated with his previous position, that of director of research. He came to the company in 1954, bringing with him experience gained in several government research laboratories.

▶ **Wayne M. Pierce Jr.,** who fills the newly-created post of vice-president for engineering and manufacturing at Norden-Ketay Corp., has been with the company since 1951, when he left Tey Mfg. Corp., now Skyworker Corp. of Milford, Conn., which he helped found. Before that he was with Chance Vought Aircraft Corp.

▶ **Bruce Seddon,** who has an impressive background in magnetic amplifiers and semiconductors and their applications in electronic control systems and circuits, has been named technical director of George A. Philbrick Researches, Inc.

▶ Two foreign scientists, both authorities on microwave tubes, have



The growing importance of
DIGITAL TECHNIQUES

As recently as ten years ago it was just becoming evident that digital techniques in electronics were destined to create a new and rapidly growing field. Today, incorporated in electronic computers and other equipment, they constitute one of the most significant developments in scientific computation, in electronic data processing for business and industry, and in electronic control systems for the military. In the near future they are expected to become a major new factor in industrial process control systems.

The digital computer for scientific computation is becoming commonplace in research and development laboratories. Such machines range from small specialized units costing a few thousand dollars, to large general purpose computers costing over a million dollars. One of these large computers is a part of the Ramo-Wooldridge Computing Center, and a second such unit will be installed the latter part of this year. The digital computer has not only lightened the computation load for scientists and engineers, but has made possible many calculations which previously were impracticable. Such computers have played a major role in the modern systems engineering approach to complex problems.

Electronic data processing for business and industry is now well under way, based on earlier developments in electronic computers. Data processors have much in common with computers, including the utilization of digital techniques. In this field, teams of Ramo-Wooldridge specialists are providing consulting services to a variety of clients on the application of data processing equipment to their problems.

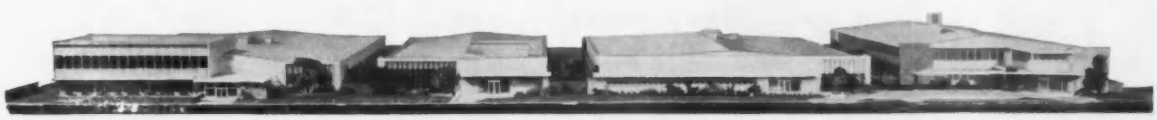
The use of digital techniques in military control systems is an accomplished fact. Modern interceptor aircraft, for example, use digital fire control systems. A number of Ramo-Wooldridge scientists and engineers have pioneered in this field, and the photograph above shows a part of an R-W-developed airborne digital computer.

These, then, are some of the aspects of the rapid growth which is taking place in the field of digital techniques. Scientists and engineers with experience in this field are invited to explore openings at The Ramo-Wooldridge Corporation in:

Automation and Data Processing
Digital Computers and Control Systems
Airborne Electronic and Control Systems
Guided Missile Research and Development
Electronic Instrumentation and Test Equipment
Communication Systems

The Ramo-Wooldridge Corporation

5730 ARBOR VITAE STREET • LOS ANGELES 45, CALIFORNIA



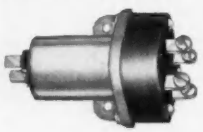
● Connect up a Guardian **RELOID** in your circuit and you have a control that carries U.L. approval for appliance assemblies. In a special version the Guardian **RELOID** carries U.L. approval marking as a ¼ H.P. Industrial Motor Starter. Guardian **RELOIDS** are totally enclosed to resist impacts, dust and moisture—compact to save space—sturdy to outlast your product—flexible in application—priced extremely low.

COIL—**Standard Voltages:** Available for operation at 6 to 230 volts, 60 cycles A.C., or 6 to 110 volts D.C. **Frequency:** Standard 60 cycles. Available 25 to 60 cycles upon specification. **Terminals:** Standard, two male A.M.P. terminals.

CONTACTS—**Rating** up to 8 amperes at 115 volts, non-inductive. **Combination:** specify either single pole, single throw, or single pole normally open or normally closed. **Insulation:** Molded bakelite, tested at 1,500 volts, 60 cycles. **Terminals:** Three contact leads plugged with molded bakelite. Specify either A.M.P. or Douglas type terminals.

GUARDIAN POWERLOID

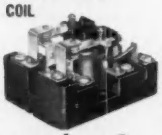
For control of 230 V., A.C. loads up to 3 H.P. Motors and 8400 Watt Heater loads. Totally enclosed. Low priced!



GUARDIAN SERIES 2100-U
25 Ampere
POWER RELAY

- INTERCHANGEABLE COIL
- NO SOLDER CONNECTIONS REQUIRED!

built to U/L specifications



GUARDIAN'S 25th YEAR

write—*on your company letterhead to arrange for a Production Sample of Guardian's Reloid. Get literature on Guardian Relays, Steppers, Solenoids, Switches.*

GUARDIAN ELECTRIC
1623-F W. WALNUT STREET CHICAGO 12, ILLINOIS
"Everything Under Control"

WHAT'S NEW

joined Varian Associates. They are: **Alfred Prommer,** an Austrian, who has been with the German firm of Siemens & Halske, and **Ronald Bell,** a Briton, who comes from General Electric's Wembly Laboratories, and the Naval Scientific Service, both in England. Prommer, who will work under Varian's **Wellesley Dodds,** head of the Wave Tube Development Dept., is an associate of the IRE; Bell's chief will be **William McBride,** head of klystron development.

▶A realignment of its corporate structure, designed to free top executives for broader responsibilities, has resulted in the following changes, among others, at Northrop Aviation, Inc.: **Robert R. Miller,** vice-president and general manager, expands his V-P duties under the new setup while limiting his managerial chores to the Northrop Div., the aviation and missile development arm at Hawthorne, Calif.; **T. V. Jones,** director of development planning, moves up to corporation level as vice-president of corporate development planning; **William F. Ballhaus** goes from chief engineer of the whole company to vice-president and chief engineer of the Northrop Div.

▶**Charles A. Nuebling,** the new manager of engineering of Fairchild Controls Corp.'s Electronics Div., has been with the Arma Div. of American Bosch Arma Corp., W. L. Maxson Corp., and Sperry Gyroscope Co. He has also had his own business.

▶Among the former affiliations of **O. A. Wright,** named engineering manager of Actuation Research Corp., are Lockheed Aircraft Corp. (engineer, Missile Systems Div.), Hydro-Aire, Inc. (chief design engineer, chief research engineer), and Weatherhead Co. (acting chief engineer).

▶**George C. Meibuhr** moves up from chief engineer to vice-president for engineering at Automation Development Corp.

▶**Orville M. Dunning,** who has been director of the Engineering & Production Div. of Airborne Instruments Laboratory since 1955, has been elected a vice-president. He came to the company from Hazeltine Electronics Corp., where he was vice-president for engineering.

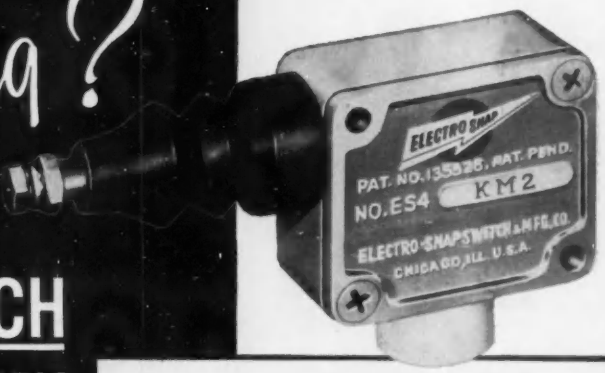
▶Federal Telephone & Radio Co. has appointed **Max Enderlin,** formerly aircraft program director, chief engineer in the Semiconductor Div. Enderlin, who joined Federal in 1943, is a former chairman of the AIEE's New Jersey Div.

▶**Hollis L. Gray Jr.,** engineering

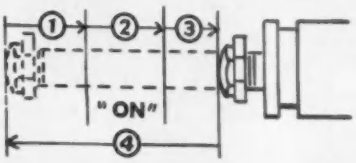
Automating? the ONE-WAY IMPULSE SWITCH

for AIR-HYDRAULIC CONTROLS

Eliminates Interlocking Switches and Complicated Actuating Dogs



EXCLUSIVE ACTUATOR LETS YOU DO THINGS YOU NEVER COULD BEFORE

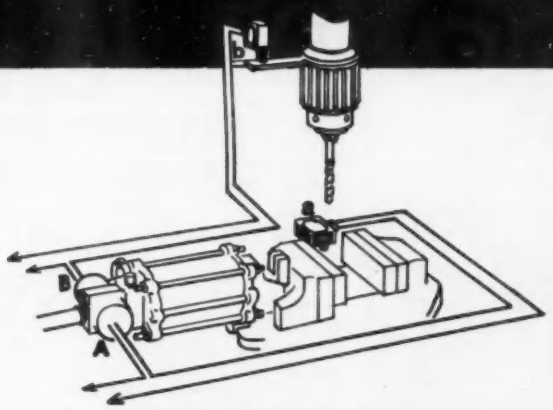


(1) Push the actuator plunger this far and switch completes a circuit.

(2) (On Period)—Circuit remains closed as plunger is pushed through position 2.

(3) (Overtravel)—Circuit is opened and remains open for rest of plunger forward travel.

(4) Switch is *not tripped* on plunger return. Circuit stays open.



SIMPLIFIES CIRCUITS

Only two Electro-Snap Impulse Switches and a double solenoid valve are needed to automatically open and close the air vise on this drill press, for example. Work positioned against Impulse Switch "a" closes vise by pulsing and momentarily energizing solenoid circuit "A". Raising drill after use operates second Impulse Switch "b" to pulse solenoid circuit "B" and open vise. No interlock switches, timers or relays.

MORE DEPENDABLE CONTROL

Troublesome one-way dogs can be eliminated. Special cams and long actuating travel are not required. No delicate adjustments.

LOWER COST, LOWER MAINTENANCE

With Impulse Switches, fewer switches are necessary. Electro-Snap Impulse Switches are $12 to $25 cheaper than timers and other switches which can do the same job. Simplicity of controls makes maintenance easy. You don't need engineers or electronic specialists.

FASTER AUTOMATIC OPERATION

Automatic machines can run faster because cycles can be more closely sequenced. There's no delay due to timer tolerances or extra machine motions to actuate interlock switches.

TRY THIS SIMPLE SWITCH ON YOUR CONTROL JOB $10.50

SEND YOUR STANDARD PURCHASE ORDER

Ask for discounts on quantity purchase

plus $.25 to cover shipping costs

SPECIFICATIONS

Housing—Switch and actuating mechanism enclosed in diecast case. Splash-proof boot protects actuator plunger.

Wire Outlet—Integral conduit boss with standard ½" —14 standard pipe thread.

Mounting—Two No. 8 screws through case.

Capacity—UL rated at 10 amps, 125/250v AC.

Pretravel 0.05".

Movement Differential 0.022".

Operating Force 3½ lbs.

MODEL NO.	Overtravel	On Period (or in. of plunger travel)
ES4-KM1	3/8"	1/16"
ES4-KM2	5/16"	1/8"
ES4-KM3	1/4"	3/16"
ES4-KM6	1/16"	3/8"

ELECTRO SNAP

ELECTRO-SNAP SWITCH AND MFG. COMPANY

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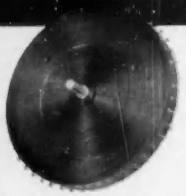
BIG PLUS in PRECISION POTS

RL-270A-1½ Precision Potentiometer . . . one of five sizes from 1¼" to 5" diameter. Nonmetallic housing has high dimensional stability, withstands −70F to +300F.

RL-270B-2 shows ganging which is available on all RL-270B models. Gamewell design requires only ⅛" per section, and external clamps provide unlimited phasing.

Gamewell *Blue Line* RL-270 A&B SERIES

RL-270A-5 is the largest in the Blue Line series. As with others, it is usually supplied with 3-hole mounting. Servo and threaded-bushing type mountings are available. Also many special features . . . send us your requirements.



Special RL-270A-5 with 48 taps, shows maximum number. Allows 47 equal resistance sections, while maintaining guaranteed linearity of ±0.1%. Total resistance of 500,000 ohms, resolution of 0.0075%.

RL-270A and B Series available in many special variations. Write for catalog and specifications and prices on your specific requirements.

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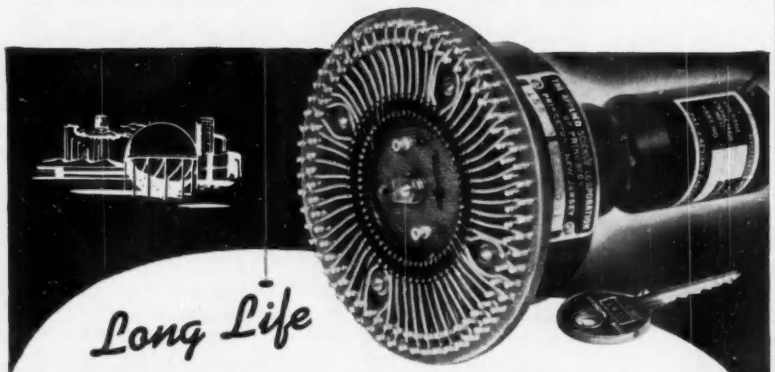
PRECISION POTENTIOMETER DIVISION



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WHAT'S NEW

sales manager of Technology Instrument Corp., has been named a vice-president. He is a CtE author (July '56, p. 80).

▶Designers for Industry, Inc., the Cleveland research and engineering outfit that is reputed to take on anything, has named two project managers who have done work in the control field. They are: **B. D. Frederico,** whose contributions include high-power coaxial switches, a linear

T. H. Smith

B. D. Frederico

electron accelerator, a digital computer, and a panoramic receiver, and **Ted H. Smith,** who is responsible for an aircraft communications system, a fully automatic fire control test set, and a peak-power radar modulator. Frederico formerly was with Bird Electronic Corp. and General Motors' Fisher Body Div., Smith with Victoreen Instrument Co. and Industrial Industries, Inc.

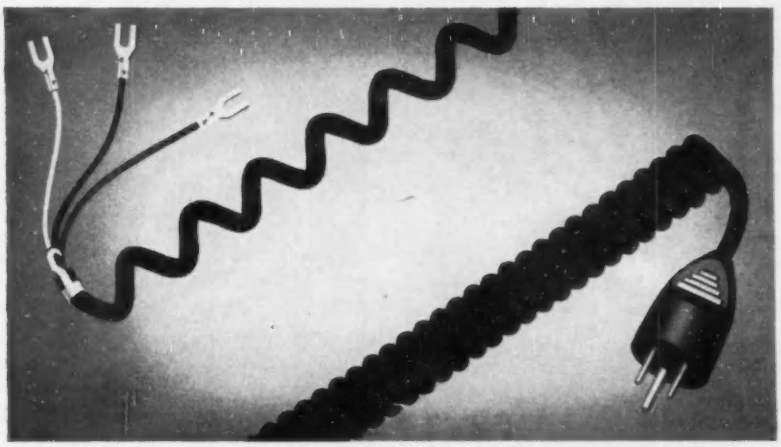
▶The Helipot Div. of Beckman Instruments, Inc., has expanded its engineering executive staff to handle several new product lines. Spotlighted are **Albert Diamond,** named chief engineer of the new Rotating Equipment Dept.; **Stanley Schneider,** named chief research engineer; **Frederick Marsh,** chief customer engineer, and **James F. Gordon,** chief development engineer. Diamond comes to Helipot from Kollsman Instruments Co., Marsh from GE's Aeronautic & Ordnance System Development Dept. at Schenectady, N. Y.; Schneider and Gordon move up from other positions in Helipot.

▶**Frank Beardsley** leaves Summers Gyroscope Co., where he has been chief engineer, to join the Automatic Controls Div. of Clary Corp. He has also been with Caltech's Jet Propulsion Laboratory, the Aerophysics Laboratory of North American Aviation, Inc., and Collins Radio Co.

▶**Robert P. Peterson,** a physicist with wide experience in the field of atomic energy, has been elected president of Applied Research, Inc. He comes to the company from Republic Steel Corp., where he was director of

Specify CL COILED CORDS

...add important convenience and safety features to your equipment!



Cords Limited COILED CORDS are engineered for specific application!

Coiled Cords, first choice in the communications industry, find numerous important applications in other fields! In addition to user convenience, Cords Ltd. Coiled Cords provide a safety factor preventing costly industrial accidents. Maintenance-wise, Coiled Cords give much longer service than straight cords by eliminating common abuses that shorten serviceability.

Product Data: A leader in the development of Coiled Cords, Cords Limited is a major supplier of this product to the telephone and communication industries. Coiled Cords are engineered for specific applications. Special oil, acid and moisture resistant properties of the jackets protect the product under unusual conditions. The most modern molding facilities for plug and conductor termination are available at Cords Limited to serve your needs quickly and economically!

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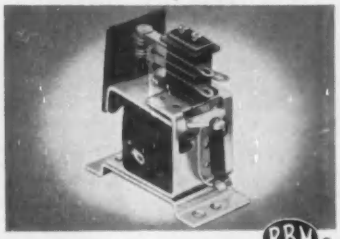

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A.C. or D.C. General Purpose Multipole relays. For circuit switching of electrical interlocking remote control devices. Features special cross-bar contacts for low-voltage, low current circuits or button type contacts for power switching circuits. Request Bulletin No. 1060.

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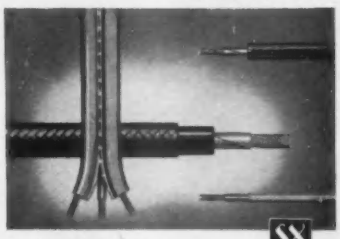
Logansport, Indiana



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Wire and Cable Division
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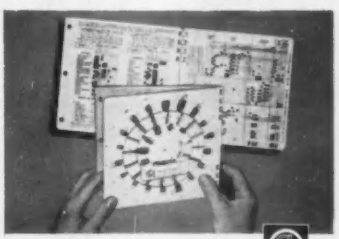

CORD SET DESIGN AID

The CORDINATOR®, a time-saving engineering tool, features simplified charts showing approved wire by product types. Dial side permits visual fabrication of cord sets and power supply cords. All components standard approved... minimizing cost... assuring scheduled delivery. Write for your free CORDINATOR.

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ADJUSTMENT
on this
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time/delay/relay

Frequent time adjustments are no problem with the dial head available on AGASTAT time/delay/relays. They provide a complete range of adjustment with 1 revolution of the dial. Dial markings permit easy calibration for accurate adjustment. And you can spot each of the 4 timing ranges quickly because they are color coded: blue from 30 seconds to 15 minutes; red from 10 seconds to 2 minutes; yellow from 0.1 to 10 seconds; white from 0.1 to 3 seconds.

Like all AGASTAT relays, units with dial heads are solenoid actuated, pneumatically timed. Each model is available with either dial head or needle valve adjustment. Where frequent readjustment of timing is necessary, dial head adjustment should be specified. For bulletin on all popular AGASTAT time delay relays, write to: Dept. A28-520.

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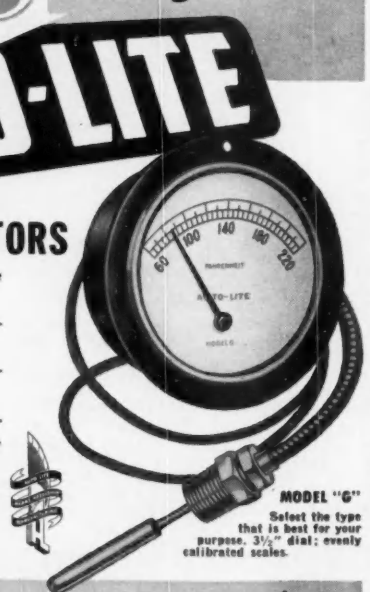
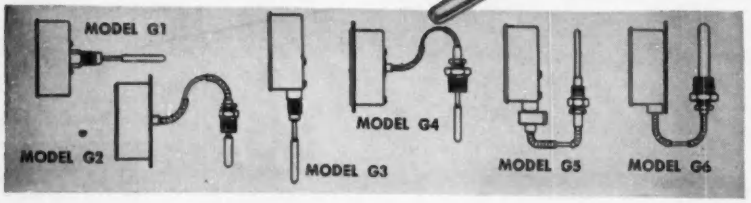


MODEL "G"
Select the type that is best for your purpose. 3½" dial; evenly calibrated scales.



WHAT'S NEW

nuclear research. Before that he was chief of the industrial and production reactors branch of the AEC's Reactor Development Div. and director of research for Sandia Corp.

▶**G. A. Walley** takes over as chief engineer at Alhambra, Calif., for Panellit, Inc. He was formerly senior project engineer.

▶Teller Co.'s new chief engineer for its Special Machinery Div. is **Charles L. Zoltani,** formerly with H. H. Robertson Co. and Babcock & Wilcox Co.

▶**Harold M. Cherry,** formerly senior vice-president, succeeds the late George L. Nankervis as president of the George L. Nankervis Co.

▶Engineered Magnetics Div. of Gulton Industries, Inc., has named **Bert McComb,** formerly with The Ramo-Wooldridge Corp., chief engineer. He is an authority on magnetic amplifiers.

▶**Allen C. Bradham,** the new chief engineer in the Penn Instruments Div. of Burgess-Manning Co., joined the division in 1947 and most recently was production engineer.

▶Bendix Aviation Corp. has filled top-level vacancies in its new Systems Div. with the following men: **Winston E. Kock,** named chief scientist in charge of surveillance and detection systems work; **John D. Trimmer,** who will take charge of nuclear systems development; **Jay E. Browder,** who will steer work in electronic countermeasures, and **William Hampton,** who will direct weapons systems projects. Kock, inventor of the microwave lens antenna, was formerly director of audio and video systems research for Bell Telephone Laboratories; Trimmer comes from the University of Tennessee, where he had been a professor of physics; Browder was formerly chief of the radio communications engineering section of Kollsman Instrument Corp.; and Hampton headed weapons systems operations at Goodyear Aircraft Corp.

▶New engineering executives of Sylvania Electric Products' Microwave Tube Laboratory in Mountain View, Calif., are: **Louis H. La Forge Jr.,** manager of engineering; **Daniel H. Goodman,** manager of research and advanced development; and **Lefler H. McKee,** manager of product design and development. La Forge joined Sylvania in 1956 after work with Westinghouse, Bell Telephone Laboratories, Raytheon Mfg. Co., and Eitel-McCullough, Inc.; Goodman in 1953 from the University of California's Microwave Tube Laboratory,

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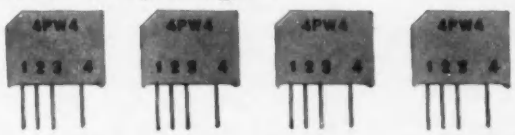

1. ENCAPSULATED R-C Network...

This new G-E development is actually several components in one unit, with performance comparable to individual components. Its thin ceramic plate, with a variety of resistor and capacitor patterns and their leads applied to customer requirements, is encapsulated in a compact, uniform phenolic case. This unit thus cuts space and solder requirements under those for individual components, in such applications as coupling, pulse-forming, and R-C filter networks. The encapsulation feature provides excellent resistance to humidity and corrosive agents, and the uniform size and surface of the case is especially suited for mechanized placement.

2. "THRU-CON" Print Wire Board...

With this advanced print wire, you can design a compact wiring pattern on *both* sides of the board *without* the cost of further processing to connect them. You gain from the "Thru-Con" additive production technique, which plates *through* the holes at the same time it plates the wiring pattern on the board.

3. "WEJCAPS" Leadless Capacitors...

Besides eliminating bothersome lead problems, "Wejcaps" offer low cost, small size, high durability, and high moisture resistance for such applications as antenna coupling networks, AVC and AGC networks, screen by-pass, and other medium tolerance circuits. The "Wejcaps" are simply inserted in a slot in a print wire board and soldered directly to the connection point.

Try these components yourself! If you're after faster production, higher quality assemblies, and lower cost—for present or prospective equipment—send *today* for this free Sample Test Kit. Address, on your letterhead please, *General Electric Company, Specialty Electronic Components Department, Section 1657, Auburn, N. Y.*

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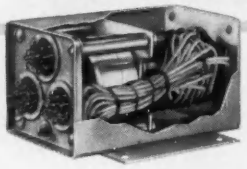
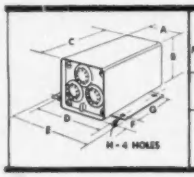


STANDARD ENCLOSURE AND STANDARD HEADERS . . . AVAILABLE ON MANY MODELS

Two standard models . . . available with a maximum of 4 wafers and 105 pins in header . . . capable of many switching combinations.

If standard Ledex models do not meet your requirements, send the design requirements for your hermetically sealed relay application today.



MODEL	MAX. NO. WAFERS	MAX. NO. HEADER PINS	A	B	C	D	E	F	G	H
No. 4	4	45*	2¼"	2⅜"	4½"	2⅛"	3⅛"	¾"	3"	⅜"
No. 5	4	105*	3¼"	3⅜"	5⅛"	4⅜"	4⅜"	2⅜"	4"	⅜"

*Circuits should allow for header pins to carry arc suppression items externally.

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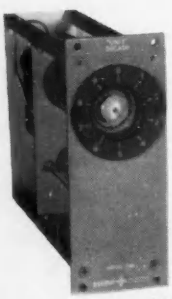

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COUNTING STRIP

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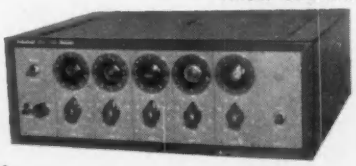

For information on various inputs, outputs, and counting units (up to 20,000 counts per second) . . . write for Industrial Bulletin — Edition II.

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WHAT'S NEW

where he was supervising engineer; and McKee in 1945 from Hazeltine Electronics Corp.

▶ **Charles Gray** is the new chief production engineer for C. P. Clare & Co.

Control Firms Fill Key Engineering Research Slots

Several control firms have moved important people into key research jobs. Among them:

Lockheed Aircraft Co., which has established a new R&D branch in the Missile Systems Div. under **Louis N. Ridenour,** director of research. Purpose of the new branch is to lace together the company's R&D and engineering facilities for optimum cooperation on government projects. Accordingly, **Willis M. Hawkins,** director of engineering, has been brought in on the project as an assistant general manager of the new branch. He will serve on a training basis for a year, then take over the R&D slot from Ridenour, while the latter will move into the assistant manager's role.

Haller, Raymond & Brown, Inc., whose new director of operations research, **Joseph O. P. Hummel,** was most recently a project chairman and senior staff member of Johns Hopkins University's Operations Research Office.

Penberthy Mfg. Co., which has named **J. C. Denis** director of R&D His appointment coincides with that of **A. N. Lindeman,** who becomes chief engineer.

Avionic Engineering Div. of General Precision Laboratory, Inc., which has named **France B. Berger** to the new post of director of research planning, and **Ivan A. Greenwood** assistant director. Berger, formerly head of the Research Dept., and Greenwood, formerly associate head, will work under **George R. Gamertsfelder,** director of research.

Abbott Laboratories, whose new director of research, **Arthur W. Weston,** has been assistant director of development since 1954. He succeeds **Robert D. Coghill,** who has resigned. Abbott's director of new product is **Frederick J. Kirchmeyer,** formerly director of new product coordination.

Associated Spring Corp., which has brought in **H. Perry Smith,** manager of the general research laboratory of Underwood Corp., as assistant director of research.

FICo engineers and produces the guidance for the Redstone Missile.
U.S. Army Photo

FICo navigational equipment goes into a wide range of aircraft.
U.S. Air Force Photo

FICo COMPUTER AND CONTROL SYSTEMS

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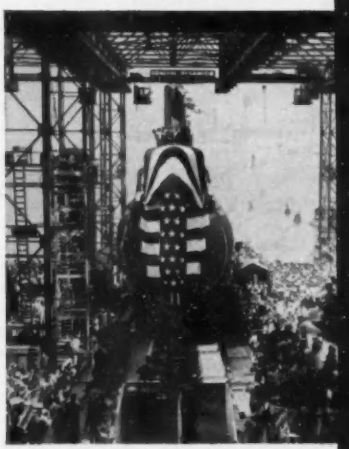
- **For Processing of Data**
- **For Special Purpose Computer and Control Applications**

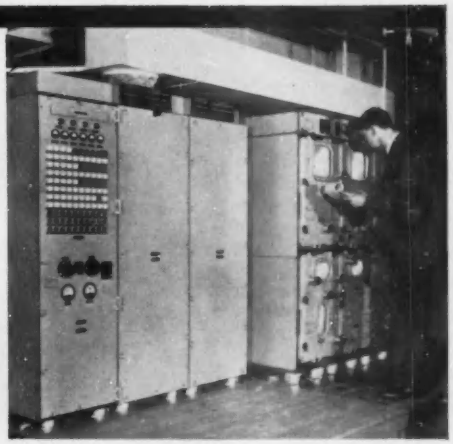
Ford Instrument Company develops and produces the most modern of special purpose computer and control systems—for missile, airborne, shipborne, land-based, and nuclear applications—for *government and industry.*

FICo is one of the foremost organizations in the United States working in the field of automatic control. Hundreds of engineers and extended precision mass production facilities enable FICo to handle complete systems contracts from start to finish.

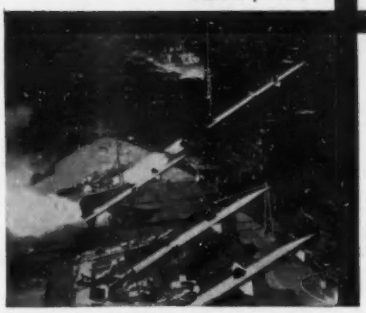


FICo controls are used in the atomic submarine program. FICo is also working toward development of the closed-cycle gas-cooled reactor.
U.S. Navy Photo

FICo research and design led to improved safety and arming device for Army atomic cannon.
U.S. Army Photo



FICo analog and digital computers can be readily developed and produced—using modular techniques—for special purpose applications.



FICo launching and control order computers are used for Navy A-A missiles.—*U.S. Navy Photo*

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VERNISTAT®
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In analog computer design, where system accuracy is directly related to the accuracy of the computing elements, the new VERNISTAT a.c. potentiometer meets the most exacting design requirements. The VERNISTAT overcomes the severe limitations placed on computer performance up to now by the use of conventional potentiometers. Errors introduced by loading, phase shift and wear are substantially reduced.

The VERNISTAT a.c. potentiometer represents a truly fundamental advance in precision potentiometer design. The combination of a tapped autotransformer and an interpolating resistance element overcomes the limitations of the purely resistive potentiometer. The VERNISTAT principle provides inherently high linearity, low output impedance, very small phase shift and long life. Relatively high output current capability and the ease with which nonlinear functions may be generated are plus features of the VERNISTAT. The unit is normally supplied as a ten-turn version and it may also be arranged for continuous rotation.

Use of the VERNISTAT potentiometer in analog systems results in a general improvement in performance characteristics. Greater simplicity, through elimination of isolation amplifiers is often an added dividend.

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vernistat®
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Norwalk, Connecticut

ABSTRACTS

Instrument Springs

From "Application of Spring Strips to Instrument Design", Notes on Applied Science No. 15, Dept. of Scientific & Industrial Research, National Physical Laboratory (England). Published by Her Majesty's Stationery Office, London, 1956.

This 25-page technical note describes the application of spring strips to flexible couplings and pivots, and methods of obtaining parallel motion and providing magnification of motion in the design of instruments. Each application is accompanied by an illustration of a typical design and the governing equations and curves for the general design problem.

The subjects covered are:

- single-spring strip pivots, essentially the design of simple frictionless hinges
- cross-spring pivots, such as those used in wind-tunnel balances
- parallel motion obtained with spring strips
- conversion of linear motion to angular motion by use of spring strips—the

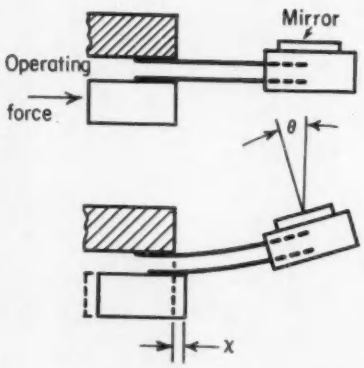

figure shows one of the several methods discussed

- the use of buckling strips and twisted spring-strips in instrument mechanisms
- indicating mechanisms based on the twisting and bending of strips
- miscellaneous applications
- methods of attaching spring strips to the mechanisms of instruments

Computer Core Memory

A high-speed core memory for digital computers using a selection system which does not require close control of the characteristics of the magnetic cores has been developed and reported on by the Air Force. The basic problem in the use of magnetic cores for permanent high-speed storage was the selection of the few cores representing a storage register and providing, with a minimum of driving tubes, the high currents necessary for reading out or writing information into this register. A solution was provided by a series-tube core memory, similar in operation to the coincident-current memory. The storage element is the same as the one in the coincident-current memory and in the core-diode memory.

The scheme uses a diode with each core. The resulting core memory achieves a random access speed of 2 microsec, the same as the coincident-current memory, but with fewer tubes. It is not amplitude-sensitive and does not require matching of cores.

The report contains a theoretical analysis and synthesis procedure for the series-type driving circuit. Experimental results from the operation of 16 single-bit registers with the series-tube selection also is included.

The volume, PB 121558 Series-Tube Core Memory, E. J. Otis, Air Force Cambridge Research Center, September 1955, may be ordered from Office of Technical Services, U. S. Dept. of Commerce, Washington 25; 44 pages, $1.25.

Measuring Small Pressures

From "Feedback Control with Conductivity Gauge for Measuring Pressures in Vacuum System" by J. H. Leck and C. S. Martin, Dept. of Electrical Engineering, The University of Liverpool, England. "Review of Scientific Instruments", February 1957.

A Pirani gage, for measuring small pressures in vacuum systems, contains a thin, constant-temperature hot wire, which acts as one leg of a Wheatstone bridge. The amount of power input required to null the bridge indicates the pressure. With manual operation, however, the gage has this disadvantage: the bridge voltage must be adjusted after each pressure change, making it difficult to follow rapid changes in pressures and prohibiting automatic recording of such pressures.

The authors review previous attempts to eliminate these disadvantages. One was to use a feedback circuit, where out-of-balance signals from the Wheatstone bridge adjusted the output voltage of an audio-frequency oscillator powering the bridge.

The circuit described by the authors,

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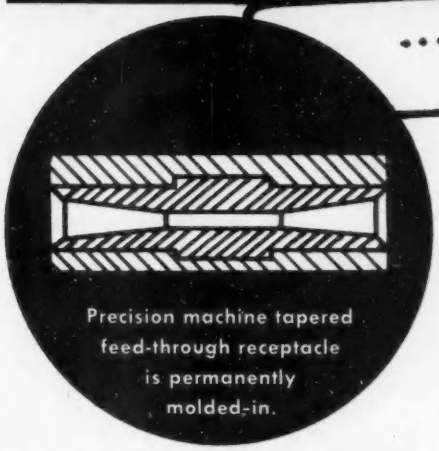

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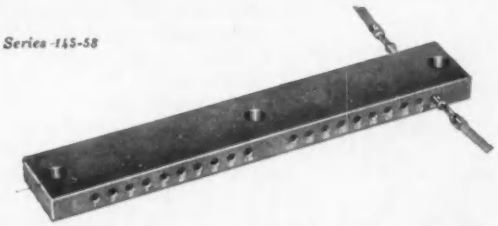

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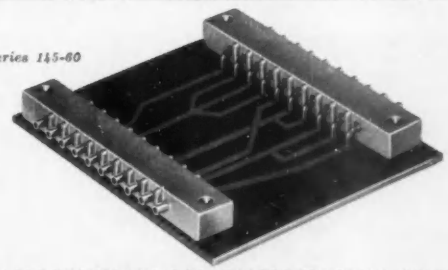

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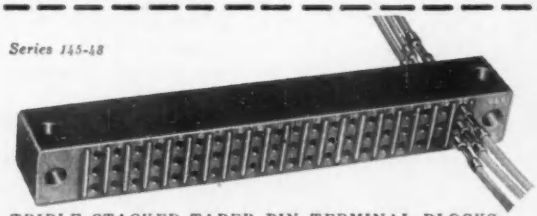

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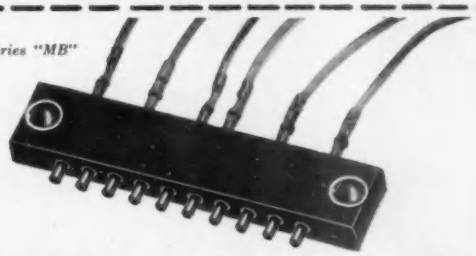

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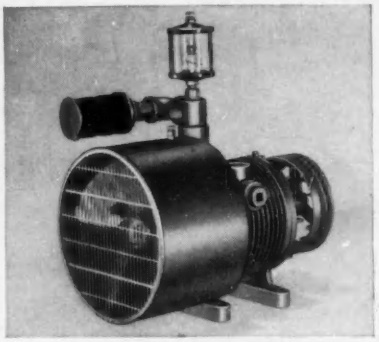

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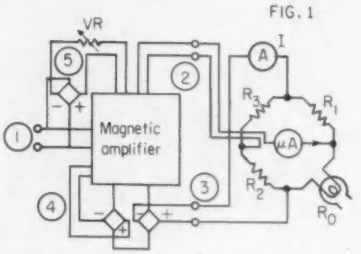
ABSTRACTS

Figure 1, also incorporates a feedback principle, but here the power supplied

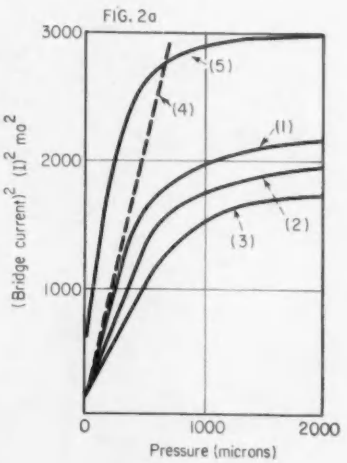
FIG. 1

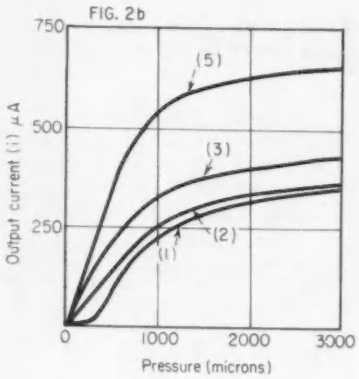


to the bridge is obtained from a magnetic amplifier. "With the bridge balanced at zero pressure (by adjusting either R_1, R_2, or R_3) an increase in pressure lowers the wire temperature and therefore its resistance to give a bridge out-of-balance current (i). The amplifier connections are such that this signal increases the bridge voltage and tends to restore balance. Thus the out-of-balance signal is very small and is approximately inversely proportional to the amplifier gauge. Both (I) and (i) are functions of pressures, as can be seen from the typical characteristics in Figures 2 (a and b). For this work commercial amplifier units with variable positive feedback, giving a current amplification adjustable in the range 100 to 2,000 (power gain 10^4 to 4×10^6) were used. The output current for a zero input could be adjusted by means of a separate bias winding. This, in conjunction with the resistors R_1, R_2, and R_3, allowed the wire operating temperature to be varied."

Curve 4 in Figure 2a represents manual control. The other curves in Figure 2a obtained with the feedback arrangement shown in Figure 1, are characterized by a pronounced droop due to saturation of the magnetic am-

FIG. 2a





plifier at around a current of 40 ma. Figure 2b shows that over a limited range of pressures the output current is substantially linear. With a regulated supply voltage, a 10-percent change in supply voltage results in not more than 1 micron in the region of the zero pressure and 3 microns at a pressure of 500 microns. An auxiliary electromagnetic relay for handling high powers can be operated directly when placed in series with the bridge supply. This should not alter the pressure-output-current characteristics to any great extent.

Self-Optimizing Control

From "Design of a Self-Optimizing Control System" by R. E. Kalman, Columbia University. ASME Paper 57-IRD-12 Presented at the Instruments & Regulators Div. Conference of the American Society of Mechanical Engineers, Evanston, Ill., April 8-10, 1957.

Prior to joining the electrical engineering staff at Columbia University, Kalman served as a member of the Engineering Research Laboratory, E. I. du Pont de Nemours & Co., Inc., where he investigated the underlying concepts of self-optimizing control systems, evaluated the alternative mathematical procedures, and then set about designing and building "a machine which adjusts itself automatically to control an arbitrary dynamic process." In the present paper the author comments on the results of his work during his tenure at du Pont.

Kalman points out that the procedure for designing a simple control system, Figure 1, can be roughly divided into three phases:

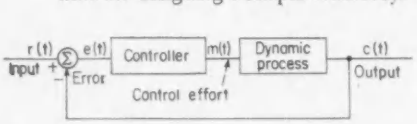
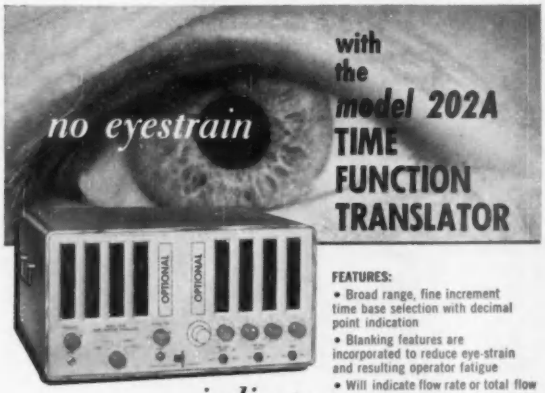


Fig. 1 Block diagram of simplest control problem



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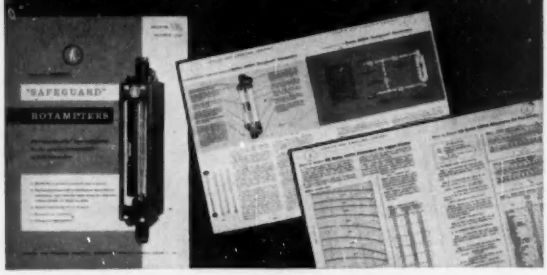

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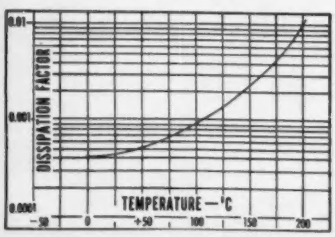

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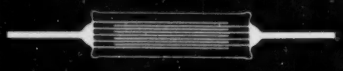

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ABSTRACTS

1. Measuring the dynamic characteristics of the process;
2. Specifying the desired characteristics of the controller;
3. Assembling a controller using standard elements (amplifiers, integrators, summers, electric networks, and so on) which have the required dynamic characteristics.

A sampled-data system which incorporates a digital computer—for its flexibility—is chosen by the author to accomplish the necessary functions shown by the controller block in Figure 1 as well as the requirements of phase 3. He states that such a computer can also mechanize the procedures of 1 and 2. "Accordingly, the problem considered in this paper can be stated as follows: To design a machine which, when inserted in the place of the controller in Figure 1, will automatically perform steps (1-3), and set itself up as a controller which is optimum in some sense." Thus the machine needs merely to measure the input and output of the controlled system; this eliminates the complications involved in the engineering design performed by a control-systems engineer. If the machine lives up to expectations, it can be connected to any process.

The author then lays down the general and the special design considerations for an actual machine built on good engineering principles:

"(1) The machine must be a digital computer which measures the dynamic characteristics of the process and then determines the best form of the controller; it controls the process by providing the required control action $m(t)$.

"(2) The operations for designing a suitable controller must not be allowed to interact with the control itself.

"(3) The determination of the dynamic characteristics of the process must be based on a large number of measurements so as to minimize the effect of measurement noise.

"(4) Among any two measurements of $c(t)$, the more recent one should be given the higher weight: Measurements of $c(t)$ made infinitely long ago should be given zero weight.

"(5) The method of numerical computation to be used in the machine should be highly efficient."

Since the machine combines the advantages of sampled-data and digital computation, the method of computing the transfer function, or dynamic characteristics of the process, should

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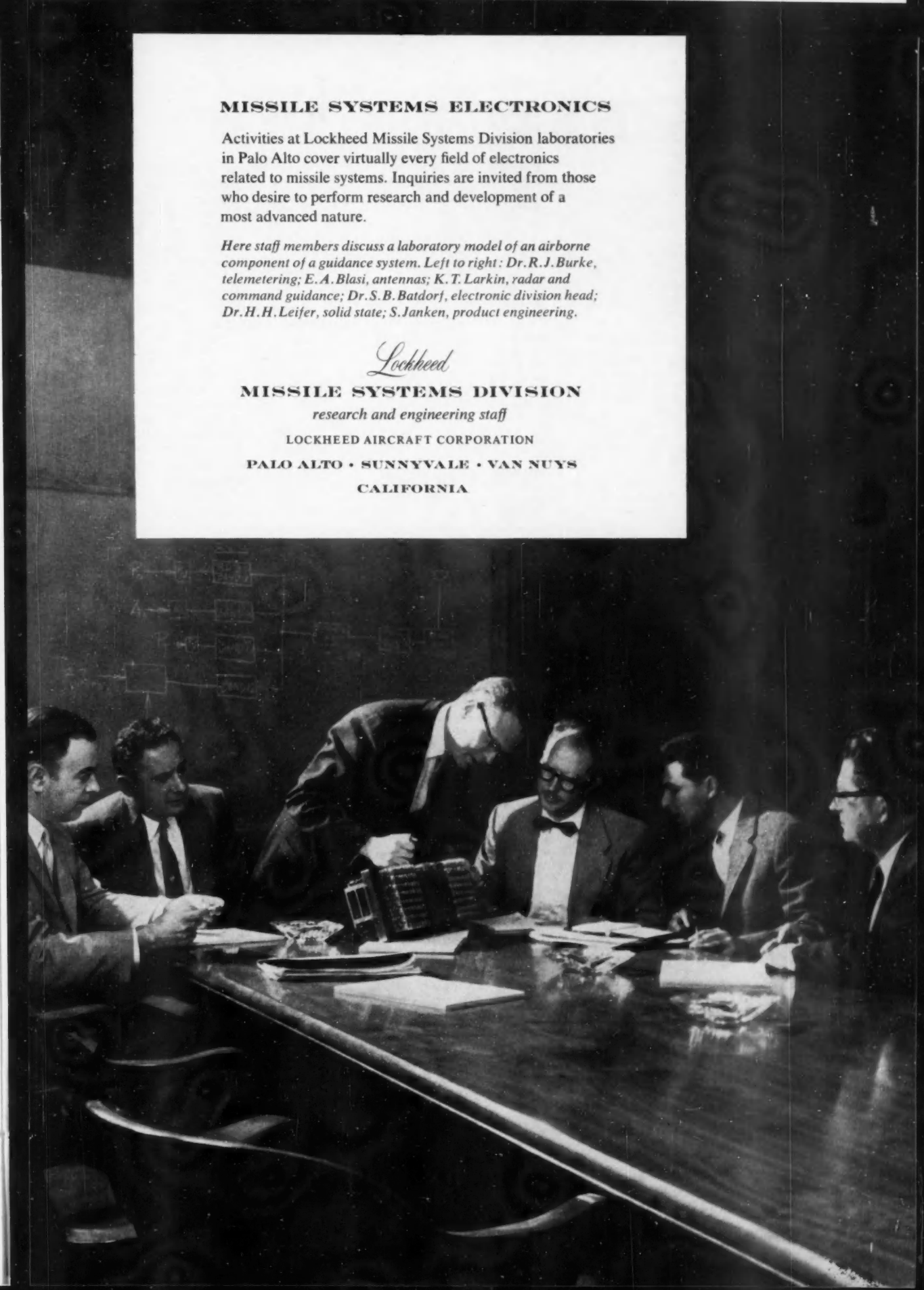

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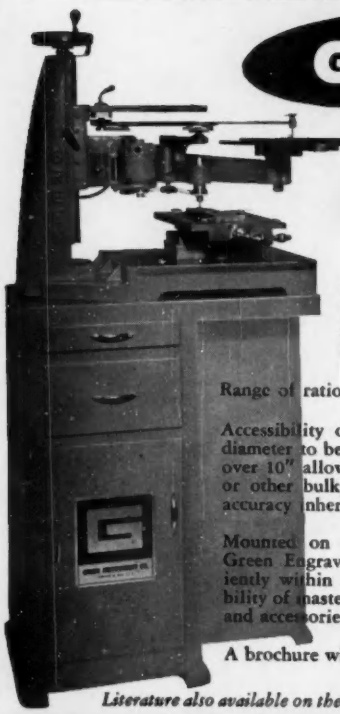

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ABSTRACTS

be appreciably compatible with these advantages. Kalman investigates the possibility of using the step response of the process, evaluates the practical considerations of the number of measurements and amount of storage required in the digital computer, and concludes that this first method does not efficiently represent the dynamic characteristics of the process.

An alternative method, which he calls the pulse transfer function, represents the process by a difference equation (see "Use Difference Equations . . ." by H. Levenstein, CtE, April 1957. Ed.), which means that only a relatively few factors and measurements are needed. In addition, the requirements for establishing the dynamic characteristics of the process by the difference equation are readily adaptable to a sampled-data digital-computer system. Therefore, "to summarize, the first step in the design of the machine is: The dynamic characteristics of the process are to be represented in the form . . .

$$c_k + b_1 c_{k-1} + \ldots + b_n c_{k-1} = a_0 m_k + a_1 m_{k-1} + \ldots + a_0 m_{k-1}$$

the coefficients of which are to be computed from measurements. The number $n = 2$ is assumed arbitrarily. In general, the higher n, the more accurate the representation of the process by the difference equation . . ." Second, "the coefficients a_i and b_i should be determined anew at each sampling instant so as to minimize the weighted mean-square (error) $E(N)$." The author also discusses the calculations necessary for determining the coefficients, pointing out that the choice of an optimum controller depends on what aspect of the system response is to be optimized.

If the foregoing considerations can be translated into numerical calculations, then the machine which has been designated in principle can now be designed in practice. However, a general-purpose digital computer, programmed to be self-optimizing, has several drawbacks: it is expensive, bulky, extremely complex, and somewhat awkward to handle. Accordingly, the author designed a small, special-purpose computer which was externally digital and internally analog. The original paper carries three illustrations of this computer, which is about the size of a file cabinet, and describes its construction in some detail. An elaborate appendix deals with the computation required of the self-optimizing controller based on the difference equations, where $n = 2$.

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NEW BOOKS

Data Processing Studies

COMPANY INVESTIGATIONS OF AUTOMATIC DATA PROCESSING. *Peter B. Laubach, formerly research associate, Harvard Business School. 258 pp. Published by Harvard Business School, Div. of Research, Soldiers Field, Boston 63, Mass., 1957. $3.*

This book reports the results of one of a series of studies conducted as part of the data-processing research project of the Harvard Business School. This project was started in 1954 and will continue indefinitely. It is concerned with data-processing systems found in business organizations, with their use by management, and with automatic equipment developed for these systems.

Laubach's study is a report of the approaches taken by various companies in investigating their data-processing needs to determine what, if any, automatic equipment they should acquire. Analogous administrative problems might arise in connection with installation and use.

Since World War II, a large number of company investigating teams have studied and evaluated automatic data-processing equipment for the purpose of informing their respective managements of the potentials of such equipment. This is a report of the steps taken by some 40 such teams, their problems and decisions.

Although these teams were all studying basically the same type of equipment, a standardized approach to the problem did not result. One of the few generalizations that can be made about the investigations was that they usually had three stages: (1) selecting and organizing the group to make the study, (2) acquiring knowledge about automatic data processing, and (3) conducting an in-company survey to determine the applicability of automatic data-processing methods to the company's particular situation. For each company these three stages commonly overlapped, and there were significant differences among the several projects in regard to such aspects as the intensiveness of the investigation, the time required, and the extent of the role of top management.

The research reported on in this book did uncover a substantial amount of information useful to project leaders in formulating their plans. Significant conclusions are drawn by the author in regard to such topics as the selection of personnel; the use of committees, consultants, and computer manufactur-

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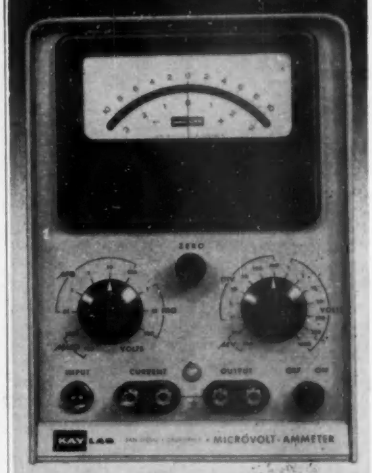

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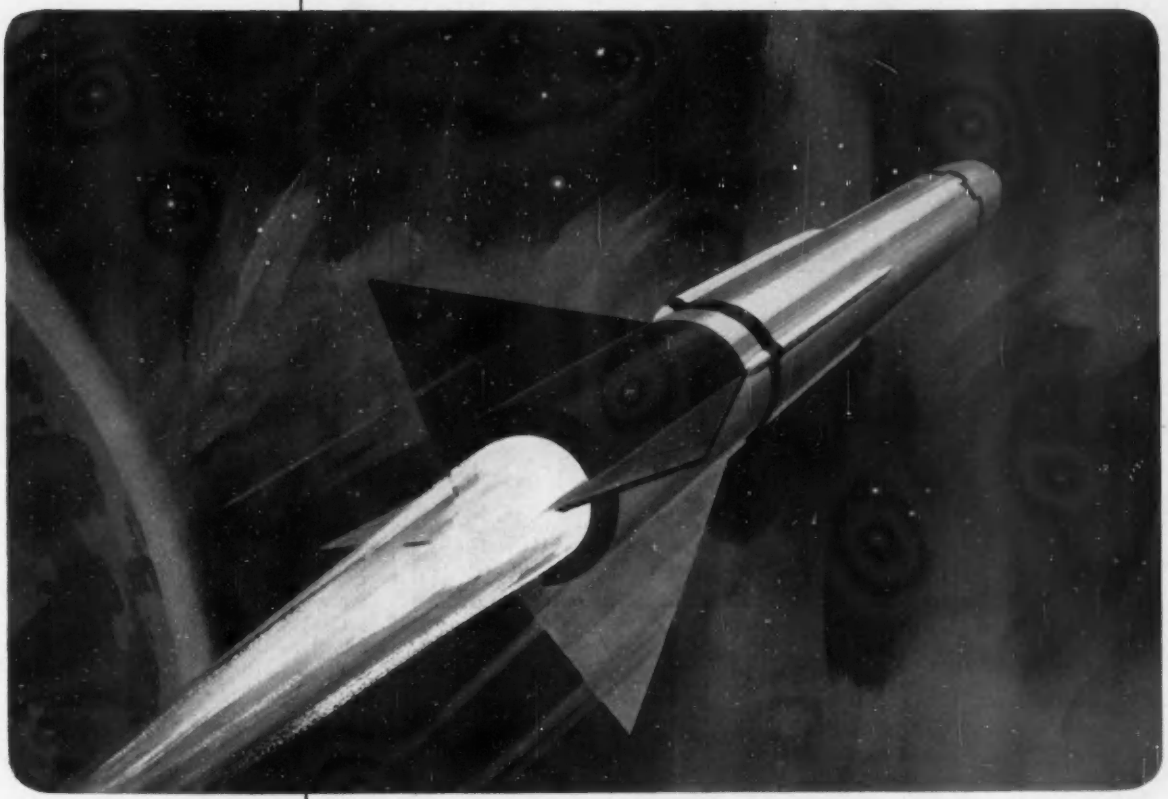

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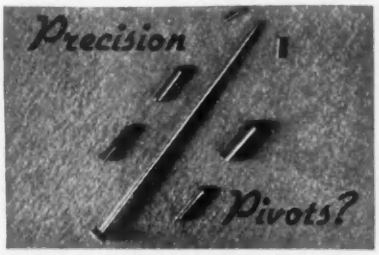
ers' representatives; the selection of applications and equipment; the use of cost and savings estimates; and the issue of whether to lease or buy.

In regard to the qualifications for members of a project team, it was concluded that a knowledge of a particular company's own accounting system was important, but that a lack of technical background in the computer field was no disadvantage to a person in learning how computers operated, determining the economics of their operation, and learning how to program and plan inputs and outputs. It generally was easier to train individuals having a knowledge of the company's accounting system than it was to teach accounting to a computer expert. It often was found, however, that accountants were likely to accept available equipment and not to realize that computer manufacturers would build equipment to suit their particular requirements. In several cases, furthermore, the presence of technically trained personnel on the project team added to its effectiveness. In several instances, company executives, consultants, and manufacturing representatives were called on to help.

Usually a company's decision to acquire automatic equipment was based on estimates of the cost and savings associated with the performance of the equipment on a specific application. The selection of the application to study was based on several considerations: the prospect of substantial dollar savings, the usefulness for "large volume" applications and applications using fairly standard procedures, and planned limitation of automatic processing to those applications which would not affect customer relations in the event of equipment breakdown.

Having selected an application, the project team estimated the associated costs and savings. In several cases, unless the application was programmed and run on the computer, the accuracy of the estimates was suspect and useful only to give answers to the following related questions: Can automatic equipment process data more economically? What applications can it handle most economically? What size is most suitable for particular needs?

If, on the basis of its investigation, a project team decided that a computer should be acquired, it then had to decide on the specific type of equipment. If the team was particularly interested in general-purpose equipment, it first decided on the size



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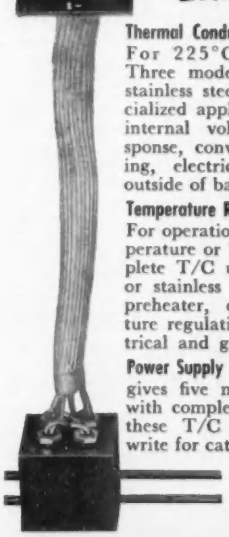

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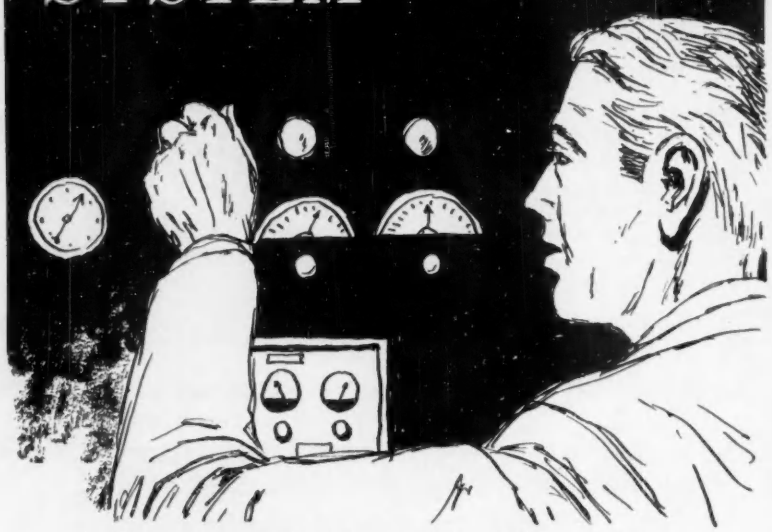

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or capacity required and next, the ability of the computer to meet the requirements of the particular data-processing system, including such matters as storage capacity, input and output methods, printing facilities, rapidity of access to stored data, the manufacturer's reputation, and the experience of other users. Cost and savings estimates were not reliable unless they covered full-capacity utilization.

In the selection of special-purpose automatic equipment, on the other hand, the teams found that they could rely on cost and savings estimates, since these estimates usually were based on full utilization. The teams also found it desirable to set certain standards for flexibility.

The alternative of using punched-card equipment was not overlooked. In many cases the use of such equipment was found to result in many, if not most, of the advantages associated with automatic equipment.

Closely associated with equipment selection was the question of whether to lease or purchase. If producers offered both alternatives, the survey teams usually considered not only the cost of each, but also their companies' cash position and alternative uses of funds, the services provided by the computer manufacturers, and other terms of the lease and sales agreements. The possibility of obsolescence, while an important consideration, did not necessarily preclude purchase.

The book also considers other topics: for example, whether to use punched-card equipment in the transition to automatic equipment, alternative methods used by decentralized companies to avoid administrative problems associated with centralized data processing on large-scale computers, and methods used by investigating teams to "sell" top management and the operating organization on automatic data-processing.

In his concluding comment the author points out that, while automatic equipment facilitates the processing of data, possibly the most significant effect associated with investigations into the use of this equipment has been the interest it has generated in improving data-processing systems. The whole field of automatic data processing has stimulated a significantly increased interest in determining what information management really needs and the methods by which this information can best be provided.

(Review prepared by Harvard Business School)

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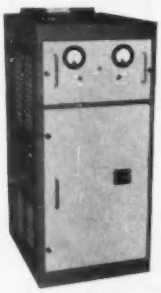

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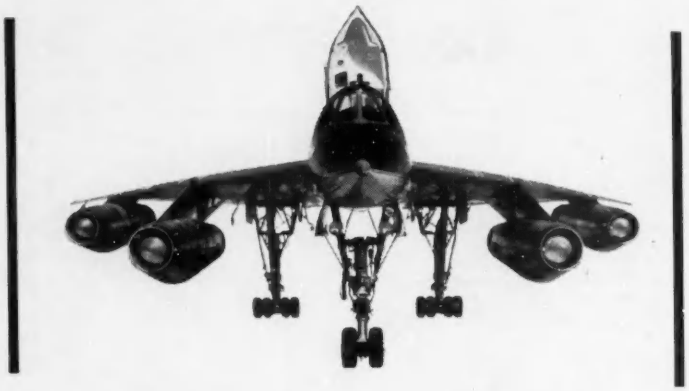

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APRIL

Second National Industrial Research Conference, "Research for Profit", sponsored by Armour Research Foundation of Illinois Institute of Technology, Conrad Hilton Hotel, Chicago April 24-25

Seventh Region Institute of Radio Engineers Conference, Balboa Park, San Diego, Calif. April 24-26

Third National Flight Test Symposium (no exhibits), Hotel Statler, Los Angeles April 29-May 2

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Electronic Components Symposium (sponsors: AIEE, IRE, Radio-Electronics-Television Mfgrs. Association, West Coast Electronic Mfrs. Association), Morrison Hotel, Chicago May 1-3

Fluid Control Institute, Greenbrair, White Sulphur Springs, W. Va. May 8-11

National Telemetering Conference, (inspection trip to White Sands Proving Grounds), Hotel Cortez, El Paso, Tex. May 27-29

JUNE

Institute of Radio Engineers, First National Symposium on Production Techniques, Hotel Willard, Washington, D. C. June 6-7

American Society of Mechanical Engineers, Semi-Annual Meeting, Hotel Sheraton-Palace, San Francisco June 9-13

Institute of Radio Engineers, National Conference of Professional Group on Military Electronics (some sessions classified "confidential"), Sheraton-Park Hotel, Washington, D. C. June 9-15

Instrument Society of America, Third National Symposium on Instrumental Methods of Analysis, University of Chicago June 13-15

Association for Computing Machinery, Twelfth Annual Meeting, University of Houston, Houston, Tex. June 19-21

American Institute of Electrical Engineers, Summer General Meeting, Sheraton-Mt. Royal, Montreal, Quebec, Can. June 24-28

British Institution of Radio Engineers Convention, Theme—"Electronics in Automation", University of Cambridge, (9 Bedford Sq., London, W. C. 1) June 27-July 1

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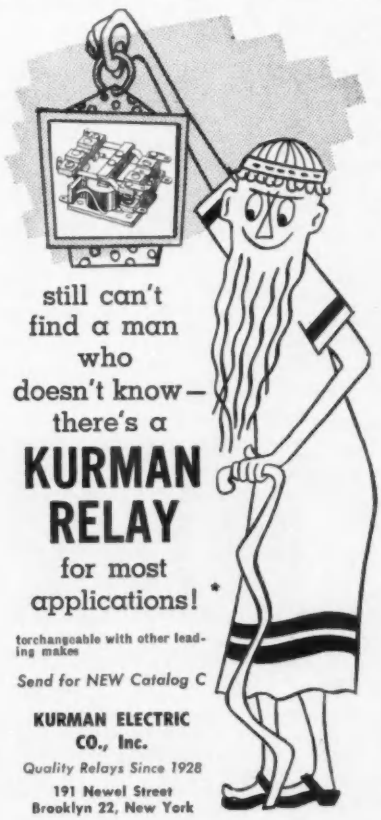

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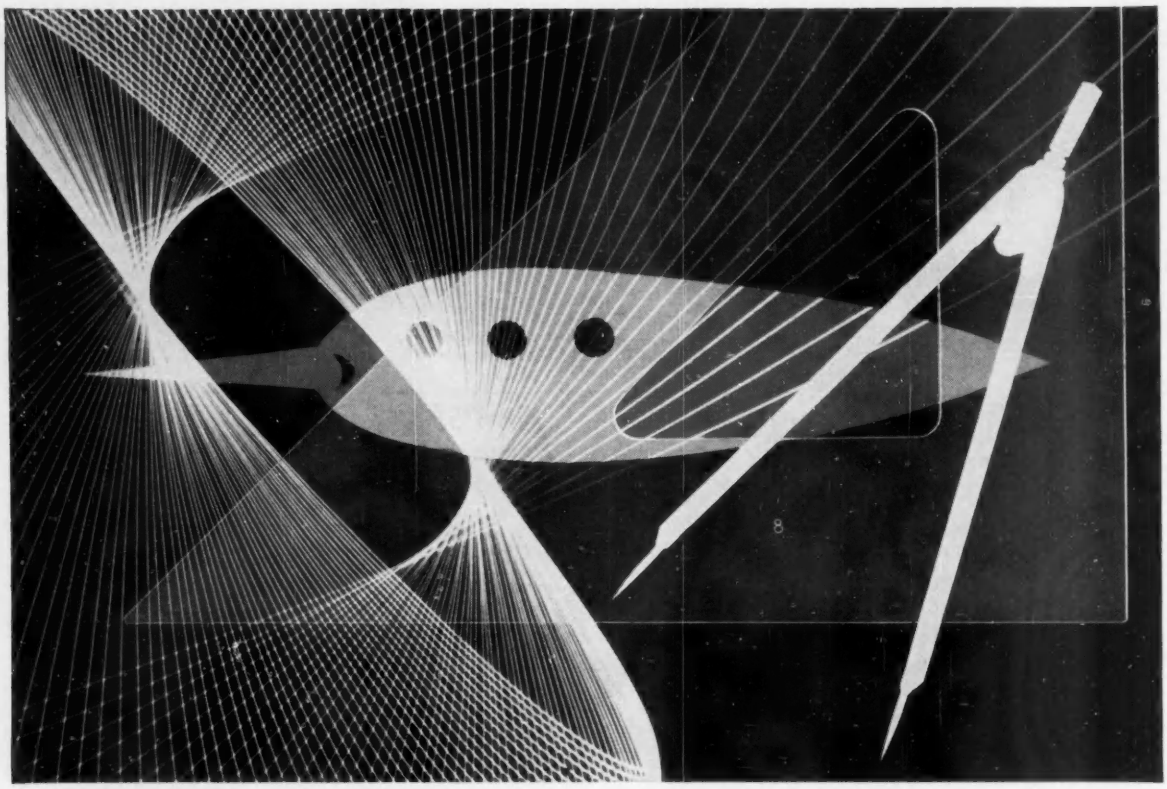

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Assistant Chief Engineer Norman F. Parker joined Autonetics in 1948 after receiving his DSc from the Carnegie Institute of Technology. Dr. Parker has been recognized nationally for his work in Inertial Navigation, and was chosen recently to present a paper on that subject at a NATO conference in Italy.

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Can We Afford a $71.8 Billion Budget?

THE BUDGET submitted to Congress by President Eisenhower for the year beginning July 1 proposes federal spending of $71.8 billion. In only four years, three during World War II and one during the Korean War, has the government spent more. Under the proposed budget the government expects to collect $73.6 billion, mostly through individual and corporation income taxes.†

The principal reason for the size of the budget and for this year's increase is an expanding defense program. About 60% of all budget expenditures in the coming fiscal year will be for national security programs. Moreover, this area accounts for about 90% of the proposed increase in federal spending. In addition, as the chart shows, there are large expenditures proposed for purposes other than defense.

Continued budgets of this size, some contend, will lead to inflation and wreck our economy. It has been suggested that they might lead to "a depression that will curl your hair." Yet many insist that the budget, large as it is, still is inadequate in many respects — for defense, schools, agriculture, small business, health, research, indeed, for almost every activity in which the government has become involved.

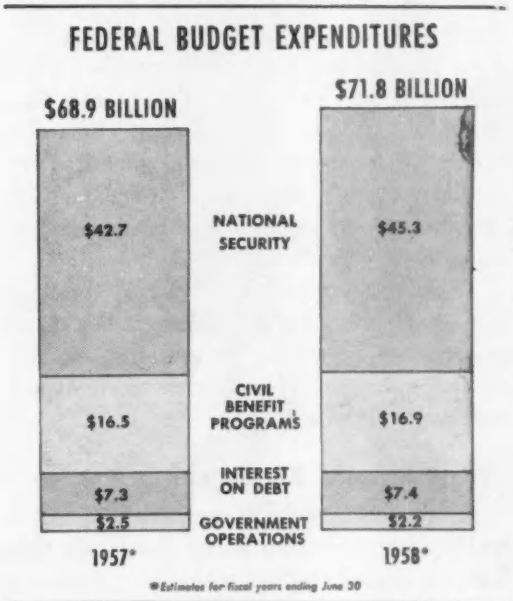
Is It Really Too Big?

Actually, the proposed budget would place no greater burden on the economy than any budget in the last six years, because our economy has been growing. Federal spending per capita under the proposed budget will be about $416, or $10 more than this year; but our per capita income rose almost $80 last year. And, because of our increasing population, next year's expenditures will, in fact, amount to *less* per capita than in 1954 when federal spending was $4 billion lower.

Another way of measuring the burden of government expenditures on the economy is to compare the purchases of goods and services of all branches of government — federal, state and local — with the total output of the nation. The share of our national product taken by government this year will be about the same as in the past two years and, furthermore, about the same as the average for the past 28 years.

By the standard of any recent year, the budget is within the means of the American economy. In this sense, we can "afford" it. But the pros-

†*These figures refer to the regular federal budget and do not include operations of trust funds, primarily for social security programs and the new federal aid program for highways, which are financed by special taxes.*



pect of steadily increasing budgets, requiring 20% or more of our national income, introduces another threat.

The Real Threat

Large and rising budgets that do not balance government spending with higher tax collections clearly would be inflationary and would destroy the value of the savings and income of all who lagged in the race with climbing prices. But serious dangers will still exist even if our budget continues to be balanced, as this year's is.

- **Budgets that require a large take in taxes eat up the savings required to finance private industry.** What the taxpayers must give the government they cannot save. This deprives private industry of the savings and resources needed to expand and modernize producing facilities.
- **High tax rates also undermine the incentive to save and invest in normal business enterprises by taking such a large share of any income gained.** Taxes on corporation income now take 52% of all income over $25,000. And taxes on individual incomes can take as much as 90% of earnings that remain after this 52% bite.
- **High taxes encourage, on the part of both individuals and corporations, the search for "gimmicks" and special treatment.** As a leading character in Cameron Hawley's novel *Executive Suite* observed: "To a far greater degree than most people realize, income tax has become a primary governing factor in corporation management." Indeed, it is only because of the numerous gimmicks and special provisions now available that high tax rates have not already inflicted greater damage to economic incentives.

These dangers comprise the real threat of large and rising federal budgets. It is a threat to continued growth of our economy, and it is no less a threat merely because the budget is technically in balance.

What Should Be Done?

In attempting to hold government spending within reasonable bounds, we should *not* hold back on needed civilian programs. The heavy demands now being urged at all levels of government for roads and schools, for instance, are largely the result of failure to keep pace with the growth of the country. Furthermore, we cannot cut provisions for national security below the minimum level of safety. And unhappily, defense in the rocket and missile age is fantastically and ever increasingly expensive.

What we *can* do is enforce some financial discipline on our military leaders, and hold down our defense expenditures by making sure their demands are justified and by requiring efficiency. In the civilian programs, though some need to be increased to serve a growing economy, we can eliminate the outright waste.

A More Difficult Job

We must also do something far more difficult, and that is to reduce federal programs of aid to special groups at the expense of all the taxpayers. The new budget calls for over $5 billion for veterans, and another $5 billion for farmers. A number of industries and areas stand to receive aid in large amounts based less on necessity than on political pressure. These demands for increased aid, year after year, must be resisted if we are to have any hope of stopping a relentless rise in our budget.

Then, as our national income increases, we can look forward to reducing tax rates and providing greater incentives for the private sector of the economy. **Only in this way — by keeping government spending in line with economic growth — can we prevent our federal budget from being a crippling burden.**

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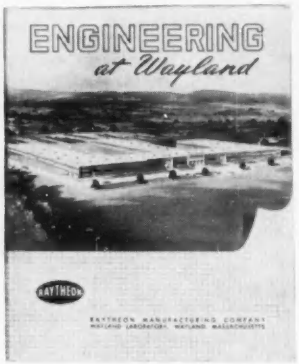

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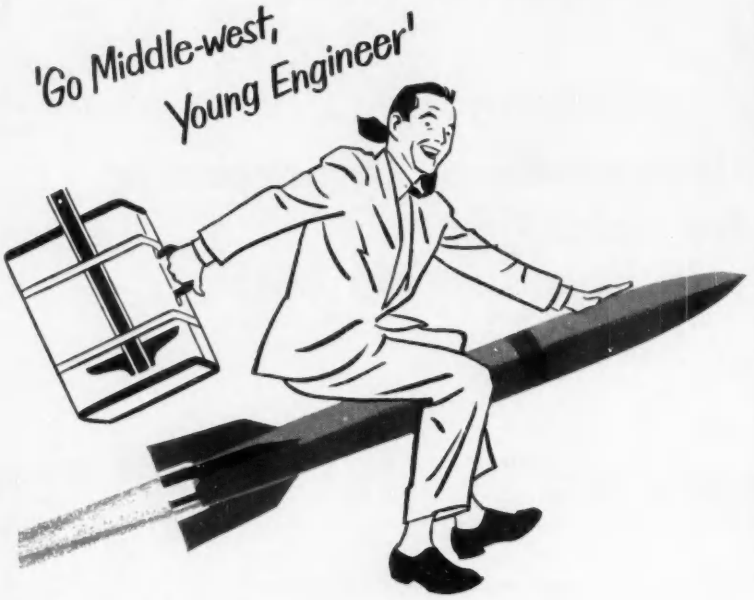

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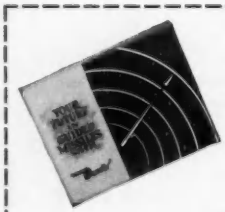

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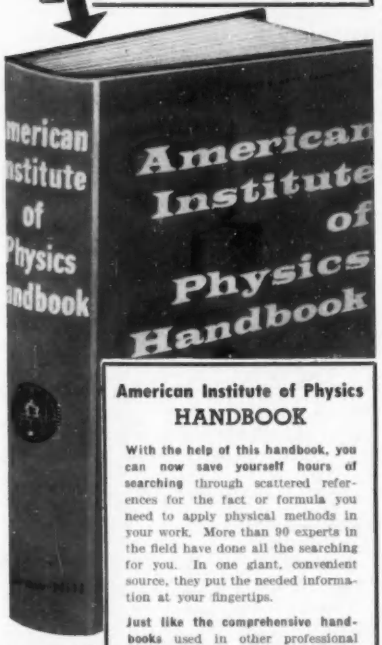

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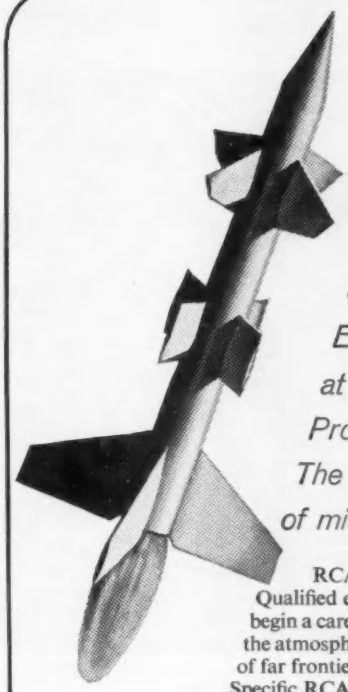

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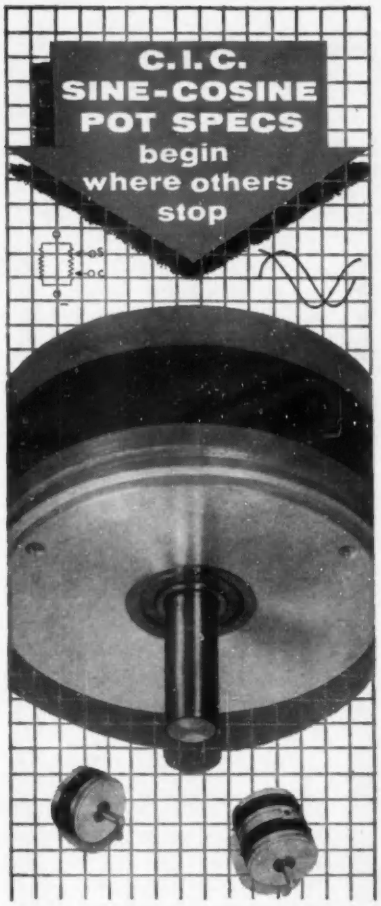

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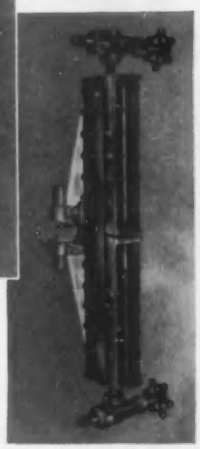

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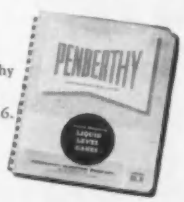

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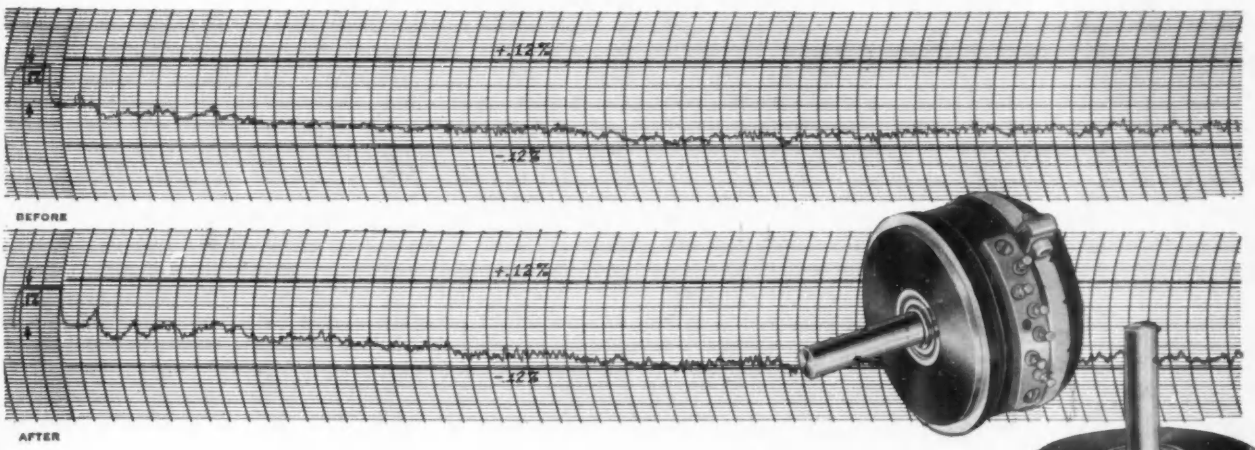

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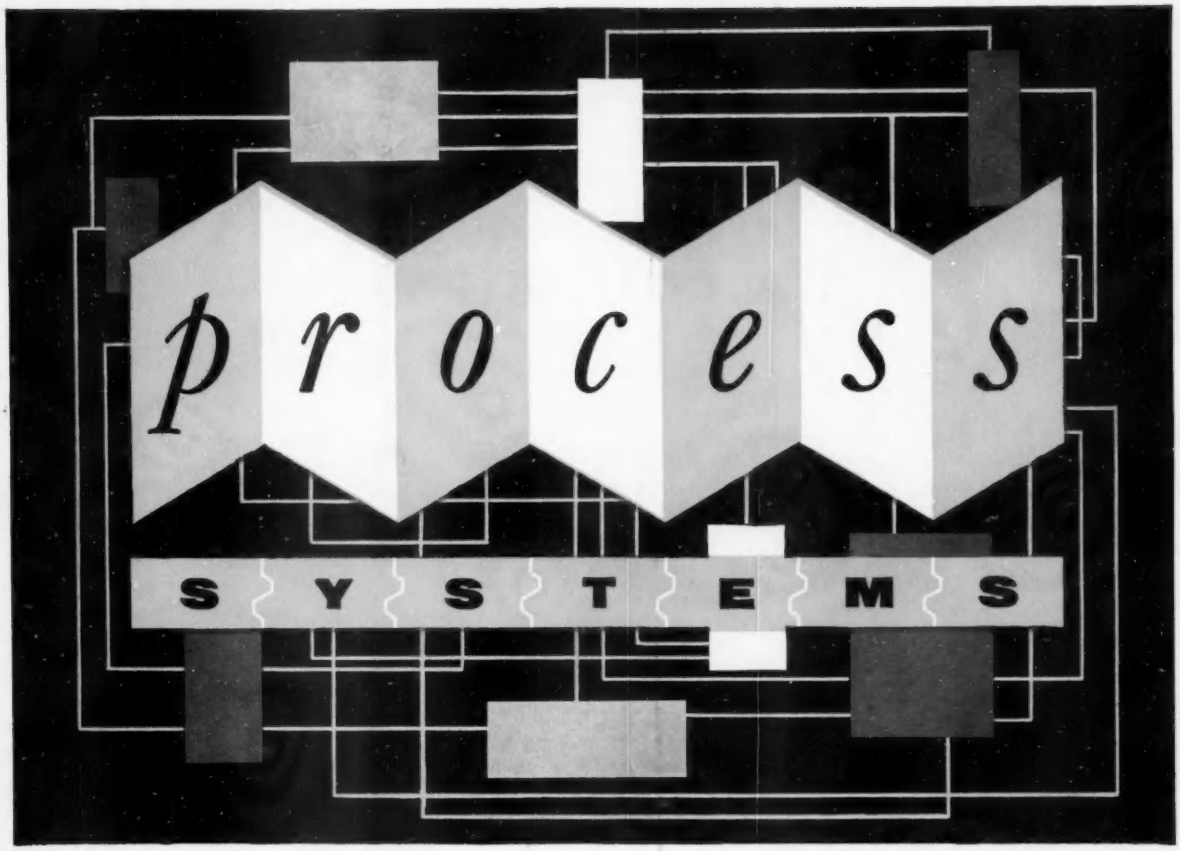

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